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Szymonik, S., Moskwa, A. S., Wójcikowska-Alot, E.

NITROGEN DIOXIDE REMOVAL FROM DILUTE GASES BY ABSORPTION IN A MAGNESIUM HYDROXIDE SUSPENSION

(Usuwanie dwutlenku azotu z rozcieńczonych gazów przez absorpcję w zawiesinie wodorotlenku magnezowego)

Results of the experiments are presented which were conducted on a laboratory scale on the NO_2 absorption from dilute inert gases by a magnesium hydroxide suspension. The results obtained are useful in the determination of the effect of some of the parameters on the process kinetics.

A serious problem in the commercial nitric acid manufacture, which has not as yet been satisfactorily solved, is the control of emission of oxides of nitrogen discharged into the atmospheric air. These oxides are highly hazardous to the immediate environment of the plant and to the whole biosphere. Irrespective of the adverse effect on the biosphere, the NO_x emission is accompanied by substantial economic losses due to corrosion of the industrial equipment and of residential houses as a result of the effect of the nitric acid subsequently formed from the oxides present in the air. The oxides are conducive also to some undesirable climatic changes taking into account their considerable share in the generation of smog.

The tail gases discharged from the absorbing towers of the nitric acid manufacturing plant contain nitrogen oxides in a concentration ranging in percentages from several to several dozen hundredth. Considering the volume of the tail gases released, this value corresponds to a few percent of the total quantity of the nitric acid manufactured. On a nationwide scale the annual emission of these hazardous compounds amounts to several dozen thousand tons in terms of 100% HNO_3 [1]. The above points to a necessity of reducing the nitrogen oxides emission.

The available methods for the removal or reduction of the NO_x concentration in tail gases may be grouped into the following three classes [2]:

(a) catalytic decomposition,

(b) adsorption on solid sorbents,

(c) absorption.

Among the methods included in class (c) worth noting is the process of NO_x absorption in magnesium hydroxide suspension to yield magnesium nitrate. This compound seems to be a good potential source of assimilable magnesium whose deficiency in the soils in this country is increasingly imminent. This material can also be used as a starting compound for the manufacture of magnesium oxide and concentrated oxides of nitrogen by pyrolysis [3].

The domestic magnesium-bearing substances which are suitable for industrial uses are dolomites, serpentinite rocks, and carnallite waste waters. From the minerals mentioned, followed by suitable chemical reprocessing, magnesia can be obtained which is good for absorption of waste oxides of nitrogen [4].

Theoretical

On the basis of the literature data [5]–[12] absorption of nitrogen oxides in the presence of oxygen in an aqueous suspension of magnesium hydroxide can be expressed by the following equations

$$2NO_2 = N_2O_4$$

$$2NO + O_2 = 2NO_2$$

$$NO + NO_2 = N_2O_3$$

$$N_2O_4 + H_2O = HNO_2 + HNO_3$$

$$N_2O_3 + H_2O = 2HNO_2$$

$$MgO + H_2O = Mg(OH)_2$$

$$Mg(OH)_2 + 2HNO_3 = Mg(NO_3)_2 + 2H_2O$$

$$Mg(OH)_2 + 2HNO_2 = Mg(NO_2)_2 + 2H_2O$$

During the absorption process the nitrite inversion occurs which can be given by equation

$$Mg(NO_2)_2 + 2NO_2 = Mg(NO_3)_2 + 2NO$$

This reaction accounts for the increase in the nitrate concentration in the absorbing liquor at the expense of the nitrite quantity. The inversion yield grows higher with temperature and with concentration of nitrogen dioxide in the gas.

Magnesium nitrate is an unstable compound and at higher concentrations in solution it decomposes even at room temperature [13]. The decomposition reaction follows the equation

$$3Mg(NO_3)_2 + 2H_2O = 2Mg(OH)_2 + Mg(NO_3)_2 + 4NO$$

The above reaction proceeds very rapidly at elevated temperatures

even at low nitrite concentration in solution to yield nitrogen monoxide as the only gaseous product.

It follows from the above analysis of the chemistry of the process that the absorption process will involve a number of interrelated and overlapping stages. Both in liquid and gaseous phase chemical reactions occur, and in both phases diffusion is operative to and from the interface. The lack of data related to the mechanism, order, and rates of all the foregoing reactions makes it impossible to determine theoretically the slowest, rate-determining step and the calculation of kinetic coefficients. Thus one is forced to resort to the experiment.

In the study on the absorption process kinetics the most commonly used method is the dynamic approach in combination with an unpacked tubular reactor [14]–[16].

The rate of any chemical process, thus also that of absorption of oxides of nitrogen in a magnesium hydroxide suspension can be expressed as follows [17]

$$r = \varphi/R = k(y - y^*)$$

where

r — the process rate,
φ — the driving force of the process,
k — a kinetic coefficient,
y — the reagent concentration,
y^* — the reagent equilibrium concentration,
R — sum of all the resistances in the system.

Analogously as for the mass transfer process [12], a relation can be derived from the balance equation for the reactor and from the absorption kinetic equation

$$G/F = k(y - y^*)_m$$

where

G — the mass flux of the component,
F — the interface surface area,
$(y - y^*)_m$ — the mean driving force for the process.

Assuming that the process is irreversible or that the equilibrium concentrations are substantially lower than the concentrations involved in the experiments, it can be admitted that

$$G = kF(y_1 - y_2)/m(y_1/y_2)$$

where

y_1 — concentration at the inlet to the reactor,
y_2 — concentration at the outlet to the reactor.

The absorption rate coefficient is a function of temperature, the gas and the liquid flow rates, and the reagent concentrations.

Experimental

The aim of this study was the experimental determination of the value of absorption coefficient for a model system composed of air-diluted nitrogen dioxide — magnesium hydroxide suspension in a saturated aqueous solution of magnesium nitrate (as one of the absorption products).

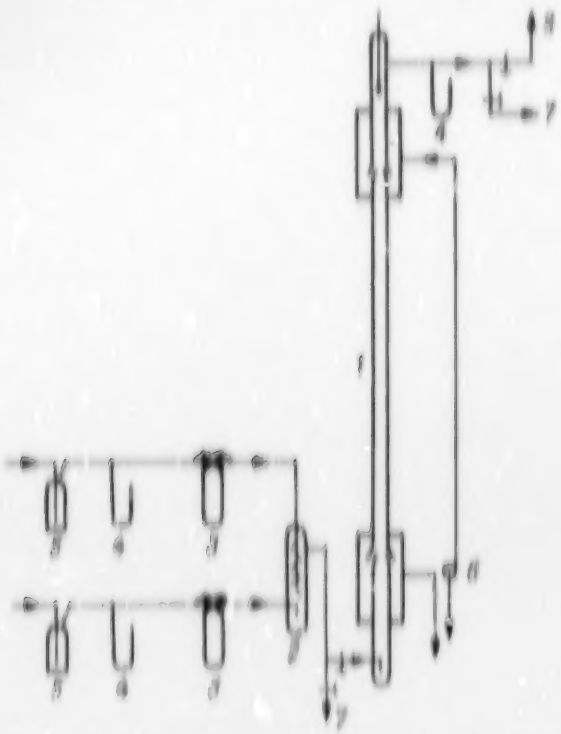

Fig. 1. Schematic diagram of the experimental setup: 1 — tubular reactor; 2 — gas mixing chamber; 3 — flowmeter; 4 — pressure gages; 5 — gas washer; 6 — liquid pump; 7 — sampling branch-off; 8 — gas outlet.

The measurement of the absorption coefficient in question was made by the dynamic method using an unpacked tubular reactor [18]; the inside tube wall, flushed with the absorbing liquor, was considered as the interface for the contacting phases. Figure 1 illustrates a schematic diagram of the experimental setup applied. The stream of nitrogen dioxide generated [19] was brought in contact with a stream of moistened air in a mixing chamber. The gases fed through the bottom section of the reactor were

flowing across the entire tube diameter, while the film of absorbing liquor was going down along the tube walls.

The absorbing liquor was prepared by adding a suitable quantity of magnesium oxide moistened with a stoichiometric quantity of water into a part of the saturated aqueous magnesium nitrate solution, and the whole was heated. Upon cooling the suspension obtained was combined with the remaining part of the magnesium nitrate solution. The concentration of magnesium hydroxide in the absorbing liquor was determined by treatment of a sample of the solution with a hydrogen peroxide solution to oxidize trace nitrate. Subsequently, a standard hydrochloric acid solution was added, and its excess was titrated with a sodium hydroxide solution. The quantity of the nitrogen dioxide absorbed was found from analysis of the gas entering and leaving the reactor. A gas sample was withdrawn with a gas pipet, into which a sodium hydroxide solution was dropped, and the contents were shaken [30]. In the solution obtained upon shaking nitrites were determined by the Griess method [31].

Results

Four series of measurements were carried out to determine the dependence of absorption coefficient upon one of the following variables:

- driving force of the process,
- Reynolds number of the gas,
- magnesium oxide concentration in the solution,
- specific spraying rate.

The experiments were conducted under the following constant variables:

- reactor diameter, 0.0197 m,
- height of the reactor effective section, 1.80 m,
- average gas temperature 22 ± 2°C,
- average liquid temperature, 21 ± 2°C,
- pressure in the reactor, 780 mm Hg.

The first series of measurements was concerned with the absorption coefficient versus the process driving force relationship. The results of that series are shown in Fig. 2. Inspection of the curve indicates that absorption coefficient increases with the driving force. This is suggestive of a rather pronounced effect of the rates of chemical reaction upon the rate of the absorption process.

Figure 3 presents the absorption coefficient versus the gas Reynolds number relationship for laminar flow conditions [32]. In the log-log coor-

dinates this relation is linear with a slope of 0.38. The value is close to the value of 0.33, i.e., to the value of the Reynolds number exponent in the formula for mass transfer in gaseous phase under conditions of forced laminar flow in a tube for the case $Re\,Sc\,(d/h) \geq 13$ [13]. The run of the

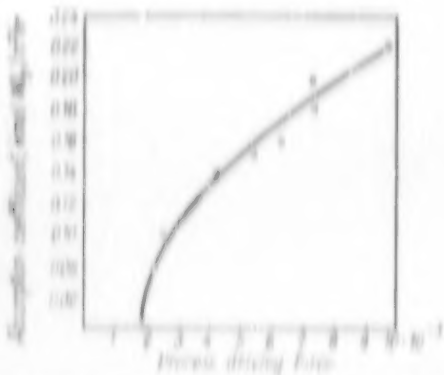

Fig. 5. Absorption coefficient vs. process driving force: $Re_g = 1700$; $l' = 0.30$ kg/mhr; $C_{MgO} = 0.5$ g/l.

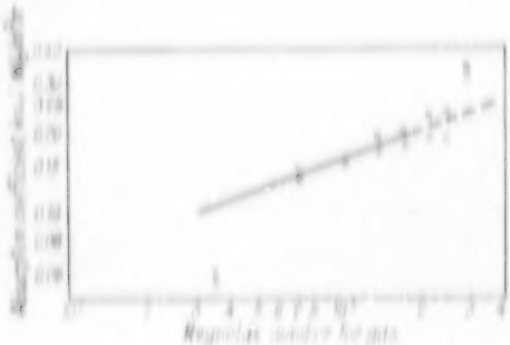

Fig. 6. Absorption coefficient vs. Reynolds number for gas: $l' = 40$ kg/mhr, $C_{MgO} = 0.5$ g/l; $y_i = 0.0081$.

curve of the absorption coefficient vs. Reynolds number clearly points to the effect of diffusion upon the process rate.

The following experimental series was made to examine the effect of the magnesium oxide concentration upon the value of absorption coefficient. The results obtained are illustrated in Fig. 4 from which it follows that absorption coefficient increases with concentration of magnesium

oxide in solution or, in other words, the effect of chemical reactions upon the process rate comes to be more pronounced.

Results of the last experimental series concerned with the study of the effect of the specific spraying rate of the liquor upon absorption coeffi-

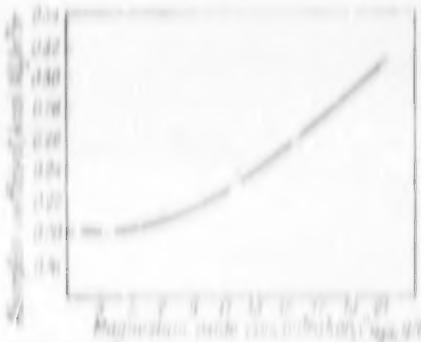

Fig. 5. Absorption coefficient vs. magnesium oxide concentration in suspension; $Re_g = 1700$; $I' = 0.30$ kg/mhr; $y_1 = 0.0081$.

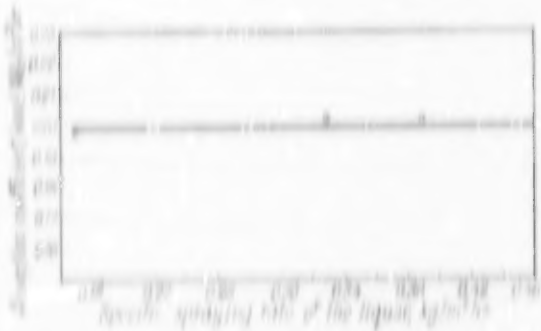

Fig. 6. Absorption coefficient vs. specific spraying rate of the liquor; $Re_g = 1700$; $y_1 = 0.0081$; $C_{MgO} = 3.5$ g/l; $d_c = 0.0197$ m.

cient are reported in Fig. 5. The relation is a line parallel to the abscissa axis; thus absorption coefficient is independent of the spraying rate of the liquor, hence the effect of diffusion processes in the liquid on absorption coefficient does not become manifest. To verify the validity of this idea additional investigation of this relation was carried out, using a tubular reactor 0.040 m in diameter and 1.00 high, under conditions of constant variables but flow rate of absorbing liquor. Results of this investigation shown in Fig. 6 are coincident with the results obtained for the reactor

of 0.0187 diameter. To sum up it will be noted that the process kinetics is controlled by the rates of chemical reaction and by diffusive resistances in the gaseous phase.

The study made should be considered as a preliminary one, which

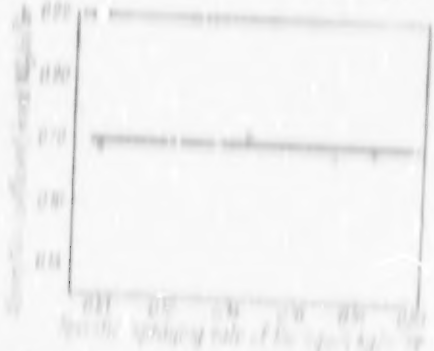

Fig. 6. Absorption coefficient vs. specific sparing rate of the liquor: $Re_g = 880$; $\varphi_l = 0.0081$; $C_{MgO} = 8.6$ g/l; $d_z = 0.040$ m.

provides merely a general idea on the question of the kinetics of absorption of nitrogen dioxide in the magnesium oxide suspension in a saturated aqueous magnesium nitrate solution as an absorption product. Magnesium nitrate can be isolated from the spent absorbing liquor. Thus the emission of nitrogen oxides into the atmosphere can be abated with concomitant production of magnesium nitrate, a potential product for agricultural use.

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Parczewski, W.

A NOVEL DAMAGE PROGNOSTICATION APPROACH FOR THE AREAS ADJACENT TO INDUSTRIAL PLANTS[1]

(Nowa metoda prognozowania uszkodzeń w rejonie zakładów przemysłowych)

Preliminary results reported for a comparative analysis of an average structure of meteorological conditions along with the results of measurements from field study indicate that prognostication of localisation of the areas particularly exposed to the adverse influence of industrial plants on the basis of the nature and dispersal pattern of emissions in various air masses provides results that are clearly close to reality, as contrasted with the results obtained using mathematical models of prognostication.

One of the most valuable damage preventive measures is the fact that a correct forecast can be made for the localisation of forest damage, and also the damage to unforested areas on which the industrial nuisance will be felt mostly. The problem has been solved on a preliminary scale by comparison of the average structure of meteorological conditions [2], [3] with results of measurements carried out at the Department of General Botany, Institute of Biology, the Nicolas Copernicus University at Toruń on the experimental plots in the neighborhood of the Nitrogen Plant at Włocławek [1].

High frequency of occurrence of labile vertical equilibrium is known to be observed with northwesterly winds. As a result, the pollutants have favorable conditions for a rapid reaching of the ground surface. Forest damage, therefore, should be located not too far away from industrial plants. In fact in the southeast direction off the plant the emissions carried from northwest direction used to reach the ground clearly 1500 to 2500 m

[1]The communication delivered at the National Organization of Technicians Meeting on Problems in the Accomplishment of the Air Pollution Control Program in Chemical Industry against Its Development by 1980, at Świnoujście, June 1975.

away from the source (Fig. 1). Beyond 3500 m essentially no injuries to pine needles and twigs could be observed.

Location of the areas particularly exposed to the harmful influence of industrial emissions was definitely differing for the air flow from the directions from the areas featured by high incidence of stable vertical equilibrium. It is known that under stable equilibrium conditions the

Fig. 1. Actual distribution of forest damage in the area surrounding the Nitrogen Plant at Włocławek, as found experimentally in 1974: *1* — serious damage; *2* — slight damage; *3* — no damage.

emissions cannot easily fall down, and for that reason the bulk of emissions reach the ground at a considerable distance from a high emission source. Actually, in the flow of air masses from the east and southeast, which carries the air westward and northeastward, the damage areas are located as far as 4 to 5 km from the source — that is, more or less at a distance three times longer than for the air flow from the northwest (Fig. 1).

It will be noted that evident damage in the area adjacent to the Nitrogen Plant at Włocławek was observed only in coniferous forests. Such damage was not, however, noted at the same distances and along the same directions in alder stands. Moreover, the floristic and phytosociological study conducted at the Department of General Botany of the Nicolas Copernicus University at Toruń could not encompass uniformly the areas situated along all the cardinal directions for reasons beyond their control.

In this connection hardly any attention is given in the above analysis to the NS, SW-NE directions. Nevertheless, the results obtained unambiguously indicate that on the basis of the average structure of weather conditions, the localization of the areas more affected by industrial emissions could be prognosticated with a rather high accuracy.

In conclusion it appears evident, even on the basis of preliminary results, that prognostication of the localization of the areas particularly exposed to the industrial pollution hazard in terms of the nature and dispersal pattern of the emissions in various air masses affords results that are clearly close to reality, as opposed to the mathematical models of prognostication. It appears quite understandable that a full analysis of the structure of weather conditions should yield even better results, seeing that a rough analysis of these conditions made to localise forest damage has been so encouraging. In order to accomplish a full analysis, a number of parameters should be estimated for many-years' period, such as: frequency of the air mass flow under labile or stable equilibrium from individual directions, mean residence time of various air masses over the area under consideration, and the mean air mass flow rate.

Obviously, the results obtained for the Nitrogen Plant at Włocławek must not be indiscriminately and uncritically transferred over other industrial plants, as the specific locations of the hazard areas will depend upon the stack heights and upon the frequency of occurrence of a variety of air masses in particular regions of the country as well as upon regional topography there. Nevertheless, the results obtained are so encouraging that the necessity of further study in this field appears unquestionable. It will be pointed out that the method can and should be used not merely for forecasting the localisation of damage areas as concerns forests, but also for other areas situated in the vicinity of industrial plants. For it is apparent that if the areas of the highest potential hazard are localized on the basis of the subjects so sensitive to emissions as forests are, the analogous unforested areas of the highest potential hazard will be determined as well. Thus the question briefly covered here should be given more attention and the soundness of the conclusions should be verified on a greater number of industrial plants.

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Kasprzycki, A.

AN OPTIMUM AIR POLLUTION DATA COLLECTION AND ANALYSIS SYSTEM

(Optymalny system zbierania i analizy danych o zanieczyszczeniu powietrza)

Collection of the possibly complete information on the air pollution hazard is needed for the analysis of the status in order to be subsequently used in a synthesis of all the available data to develop the pollution growth prognosis, and to consider possible countermeasures as well as improvement of the starting conditions. Systematic, reasonable and fast use of the comprehensive data bank and data analysis should be based on the advanced electronic data processing equipment.

The objective of an air pollution monitoring system for data collection for a given protected area should consist in collecting possibly the most complete data on the pollution hazard. Such a data bank would next be used for the analysis of the pollution status, followed by a synthesis of all the available information to develop a prognosis for the pollution growth, and to consider diverse practicable variants to counteract that growth and also to improve that status. Evidently, a good data collection system should be possibly the most economically sound — that is, the entropy of the system should attain a maximum value with respect to all the components of the system treated as a set of random events. To achieve the goal which the system is to serve as, for instance, the development of the pollution growth prognosis and a possible reduction of emission, the development of a series of mathematical models is indispensable which would be an essential part of the system and would in a way limit that system. Thus, the air pollution data collection should be consistent with the assumptions of the model series adopted. Attention will be called to the fact that the computer simulation based on a possibly simple, but corresponding to reality, mathematical model of pollutant dispersal in the area under consideration is the best possible research method to be helpful in a reasonable development of preventive measures on a global scale.

The major components of the system of the air pollution hazard data for the area in point thus defined may be discerned as follows:

— a series of mathematical models of a physical and statistical type, which are determined by the tasks to be solved on the basis of the data collection system;

— a detailed emission source inventory for a given area with a subdivision into point source and unorganized sources (e.g., area sources);

— an emission monitoring network collecting data on the ground level concentration of pollutants characteristic of the area in point;

— a local meteorological station that provides necessary data for the description of the dispersal of pollutants in the atmosphere in terms of suitable mathematical models;

— estimation of the background concentration of the emissions as measured from the outside of the area considered under diverse meteorological conditions.

A detailed analysis of individual system components should be made.

Emission Dispersal Modeling

Generally two major approaches are known for the mathematical description of the dispersal of atmospheric emissions, namely:

— physical models, which describe the effect of diffusion of emissions in the atmosphere from the condition of the atmosphere and the emission value known;

— statistical models, which correlate the ground level concentration (GLC) values on the area of interest with the variations in meteorological parameters and sometimes also with the emission characteristics on the basis of the analysis of the series of measurement data.

The physical models represent some simplified solutions of the equations of motion of a gas molecule for the surface layer. Their soundness critically depends upon the manner in which the model parameters were determined under the location and meteorological conditions of interest. The use of more exact, thus involved mathematically, models is advisable merely when the model parameters can be relatively accurately evaluated, as otherwise the results of calculations are not improved. In considerations concerned with the emission reduction over a specific area, as well as with the demarcation of protective zones, location of recreational areas, residential areas, etc., it is indispensable to develop a strategic (climatological) model that would correlate the spatial distribution of the GLC value with the average emission volume and its distribution over the area of interest. An essential factor in that task is a correct evaluation

of the many-year (for a period of 10 to 20 years) distribution of meteorological parameters in a given area (frequency of wind directions and velocities in a given stability class, frequency distribution of the stability classes, mean mixing heights, etc.)

In the case the atmospheric emission can be temporarily reduced by suppression of pollution from some large plants (e.g., thermal power plants which can switch for some time to a low-sulfur fuel), a series of tactic (short-term) models should be evolved for particular meteorological conditions when the ground level concentrations attain maximum and minimum values.

Statistical models can be worked out for a given area solely if a GLC monitoring network is available and enough data has been gathered from duly prolonged and uniform measurement series.

The purpose of the statistical models is a true description of the atmospheric endangerment conditions involved on the background of the existing air quality standards, and forecasting of changes in the local endangerment by prognostication of meteorological factors in a meso- and macroscale. A correct application of statistical models, especially those of a simpler kind is essentially possible only when the emission rate cannot be actively affected. The most promising, however, is the application of a statistical model based upon empirical orthogonal functions to the data collected on a fixed monitoring network. The model, which requires a large and fast computer, permits the time-space field of the GLC data to be split into two parts, one of which is time-independent (eigenvectors), and other is space-independent, i.e., it is independent of the location of fixed measuring points (the time eigencoefficients correlated with the eigenvectors). This approach is good for a synthesis of the measurement data from a local monitoring network of any size which can be made by determination of the correlations of the time eigencoefficients with variation of meteorological elements in a meso- and macroscale. Variation in time of the emission rate of individual sources can also be accounted for quantitatively (by eigenvectors).

Emission Source Inventory

The stepwise inventory of emission sources, which consists in a gradual including of smaller and smaller point and area sources over a given area, is a major approach to provide information on the pollution hazard of the area of interest. This inventory should include the following:

— large and high point sources, as concerns the parameters indispensable for the development of the diffusion model (emission rate, emission

characteristics, stack height and diameter, temperature of the discharged gas, gas discharged velocity);

— medium and low point sources, as concerns the same parameters as indicated for the high sources;

— area sources, as concerns estimation of the emission characteristics and emission rate.

Local GLC Monitoring Network

Over the area protected and exposed to the hazard of dangerous pollution of the surface air layer, a monitoring network should be set up to measure GLC of the emissions characteristic of the area of interest.

The major tasks of GLC data collection may be defined as follows:

— determination whether or not the accepted air quality standards for various averaging times (e.g., 20-min or 24-hr averages) are exceeded for definite airborne chemical substances and deemed pollutants;

— supply of the data required for the verification of the strategic and tactic pollution dispersal model;

— formation of a temporal measurement series requisite for the development of a statistical model for the relation of the global GLC over the whole model area and the meteorological parameters by means of orthogonal functions (the most recent models);

— estimation of the pollution background of the pollutants coming from outside the area involved in the mathematical modeling.

For economic reasons, as mentioned previously in this article, the monitoring network should be optimal, i.e., such as to ensure reliable solution of the tasks at hand being at the same time possibly the smallest. The network should be of a fixed type, and should be equipped with instruments for a routine recording of concentration of a variety of atmospheric pollutants, best with automatic analysers. The location of the measuring point should result from both the need for a constant check upon the air pollution level at sites of particular significance (near hospitals, large concentrations of the public, sanctuaries of nature, etc.), and the necessity of a continual improvement of the strategic model of the emission dispersal and improvement of the series of the tactic models. The initial location of the measuring points can be set up on the basis of a simple climatological model. This location will include, for instance, only emitters of the area and the many-year frequency wind rose from the nearest weather station. The basic measuring points should be located at the sites of the expected maximum emission concentrations. To estimate the background that comes from the outside of the area of interest, measuring points can be used that are situated near out-of-town hospitals, sanctuaries of nature,

and the like. For a better description of the pollution level on the area of interest the location of measuring points can be changed after a certain time. The period of operation of an established monitoring network, however, should not be shorter than the uniform time interval required for the development of a sufficiently reliable statistical model based on the empirical orthogonal functions. Such intervals will be shorter in the case of analysis of the measurements of a short averaging times, e.g., for one-hour GLC values. For 24-hr GLC measurements the interval should be of an order of, e.g., the whole heating period within a year.

Local Meteorological Station

On the highly polluted, congested areas, where additionally plans are made to reduce emission within the framework of a tactic program with respect to certain large plants under circumstances of meteorological conditions that are particularly hazardous to public health, a local meteorological station is to be set up with the following research program:

— hourly measurements, perhaps with continuous recording, of the fundamental surface meteorological elements, i.e., wind direction and speed, temperature, humidity, cloudiness, maximum and minimum diurnal temperatures, precipitation, pressure, and atmospheric phenomena;

— continuous recording of the long-term radiation balance;

— recording of the azimuthal turbulence of wind, wind elevation and velocity;

— aerological measurements: at least twice a day (before sunrise and early afternoon), radiosounding of a lower-troposphere type up to 3 km, as concerns the determination of profile of wind direction and speed, temperature and humidity profiles.

Results of the local, e.g., two-year meteorological measurements from a requisite basis for the following analyses to be performed:

— correction of the many-year meteorological data, e.g., from a 30-year period from the nearest fixed synoptic station, which is necessary for the development of a strategic model of the average GLC values for a given area (frequency distribution of the wind direction and speed in a given stability class, frequency distribution of the stability classes, and of the stagnation periods);

— determination of the frequency of occurrence, height, and the value of the ground temperature inversions;

— determination of the average mixing layer thickness (height of the upper inversion base) in individual periods during the year and in peculiar meteorological conditions;

— exact description of the stagnation periods that present nuisance to the public;

— supply of the data necessary for the formation of a series of tactic models for peculiar meteorological conditions and to set up a statistical model for the whole monitoring network (based on the empirical orthogonal functions).

Analysis of Information Obtained from the Data Collection System

Reasonable and fast use of the collected comprehensive information on the emission rate, GLC values in individual points of the monitoring network, and the meteorological data from the local station is possible only if accomplished with the use of the advanced information means (statistical punched cards, perforated and magnetic tapes).

Analysis of the data collected in the data bank, followed by their synthesis, should be subordinated to a superior goal, for the accomplishment of which the data collection system has been devised. Generally speaking, the following common features can be seen in every system of that kind:

— Fast analysis of the GLC data to ascertain whether or not at a point of interest and in a given time the air quality standards are exceeded. In case of the active interaction intended with respect to the emission volume, it is necessary to set up an alarm system with the central collecting and recording of the current GLC data at the particular network points. Otherwise an immediate telemetering is not required.

— Continual updating of the data on emission and its variability with time on the area under surveillance, e.g., in the daily, weekly or annual period. Moreover, all the requisite emitter parameters should be recorded, which are useful in the estimation of the initial mixing of the pollution plume from point sources, decay of the pollutants in the atmosphere as a result of photochemical reactions, gravitational sedimentation, washout, etc.

— Current analysis of the data supplied by the local meteorological station as well as the general synoptic data for the area of interest (synoptic reports in a macro- and mesoscale, containing maps of the lower and upper topography for the surface from 850 to 700 m) and meteorological forecasts.

— Current synthesis of the measurement data for the economic uses of the area of interest. A synthetic processing of the data collected in the air pollution control system is requisite for conclusions to be drawn, for taking economic decisions, and for a possible temporary decrease of emission on the area in point. In the advanced management system the de-

visions that imply economic effects (e.g., expensive projects to clean waste gases from large manufacturing plants, etc.) should be taken after a suitable quantitative analysis of the available pertinent factual material, best on the basis of the decision function peculiar to the problem at hand (e.g., temporary change of the thermal power plant from high-sulfur to a low-sulfur fuel which is more expensive and stored in small quantities, etc.). A quantitative synthesis of a large body of uniform measurement data (e.g., on GLC level) is possible only by statistical modeling approach (regression models, empirical orthogonal functions, setting up decision functions by the method of confidence intervals, etc.). On the other hand, the specific measurement data, such as those provided by aerological sounding and emission source inventory, should in the first place be used in the physical models of emission diffusion. Both the statistical and the physical models that correlate directly the effect (GLC level) as a function of cause (emission) should be gradually improved and updated as the information piles up in the data bank of a given system.

A correct implementation and an optimum performance of the adequate advance data collection and analysis system for the atmospheric pollution hazard for a protective, isolated area should be preceded by a possibly detailed definition of partial goals, to which the system will be subordinated. In the following stage the most suitable mathematical models should be chosen for a given monitoring network, and preliminary numerical calculations should be made on the existing and interpolated (or preliminarily assumed) measuring material, and the analysis of the accuracy (analysis of error) should be carried out for the results obtained for a number of the admitted variants of location of the monitoring network. Once the optimum monitoring network and a gradual accomplishment of the project have been established, the results obtained should be all the time analyzed with a constant use of electronic data processing technique. The data collection without having an analysis and synthesis system developed as well as a further processing of this data, as a rule, result in a loss of information on account of limited handling capacity of the computer units and the fact that not all the measurement data is used which not frequently was collected just in case on the basis of a general qualitative knowledge. Moreover, the emission data and GLC data cover usually a period of two or three years at least.

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ESTIMATION OF INDIVIDUAL DUST HAZARD IN THE WORKING ENVIRONMENT IN A SUPERPHOSPHATE PLANT

(Ocena indywidualnego zagrożenia na działanie pyłu w środowisku pracy na terenie fabryki superfosfatu)

Results of the determinations of superphosphate dust concentration are reported, which were carried out at seven workplaces with a Casella personal dust analyzer. Analysis of the results showed that the most hazardous working conditions injurious to the respiratory system were those for operators of comminution, classification, and granulation processes.

In recent years a renewed interest can be noted in industrial medicine for the question of the nonspecific chronic respiratory illnesses among the workers exposed to deleterious factors in the working environment inclusive of process particulates. Despite a substantial research done on particulate emissions in manufacturing plants available in literature, most of the papers are concerned with measurements of overall dust concentration inside the production rooms, while rather infrequently they deal with individual hazard for a worker [1], [2], [4]–[6], [8], [10], [11].

To find the cause-effect relation between dust concentration and the incidence of the nonspecific chronic respiratory illnesses, the most essential is to determine the individual exposure of the worker to respirable dust fraction while he is performing his professional operations during the entire workday [3], [7], [11]. Fine dusts of a size below 5 μm in diameter are not only harmful to the lower respiratory tract but equally so to pulmonary tissue itself [11].

Epidemiological studies on the effect of particulate contaminants on health of workers employed in a variety of manufacturing plants have been undertaken by the Department of Epidemiology of the Institute of

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Social Medicine of the Medical Academy in Cracow. In this connection a program has been developed for the analysis of individual exposure to fine particulates of the crew of a superphosphate plant. Superphosphate dust is harmful not only to the crew of the pertinent plants but presents a hazard also to farmers, as this chemical is a widely known fertilizer.

Experimental Data and Philosophy of Measurement

The experimental data gathered encompasses measurements of dust concentration in seven occupational categories. In the selection of a particular workstand the most typical conditions were considered. On the other hand, at the workplace of the fertilizer transport operator, on account of

Fig. 1. A photograph of a worker equipped with a Casella dust analyser.

the diversity of operations performed and a considerable number of operatives employed there, the measurements were carried out at two various stands (Table 1).

Measurements of dust were performed by means of a Casella personal

dust analyser. Due to its small size and lightness, it is convenient during operation (Fig. 1).

The research program provided the measurement of individual dust concentration at each workplace with two dust analysers. One analyser was equipped with a cyclone to stop on the analyser filter only the respirable fraction of dust (below 8 μm), and the other was provided with a filter head to determine the total dust concentration. To see a possible difference in dust concentration in the first and the second half of the workday, the filters were replaced every four working hours. It will be noted that during the sampling the worker equipped with the analyser was under a constant watch. Moreover, to ensure adequate accuracy of the

Table I
Categories of the Workplaces in the Superphosphate Fertilizer Plant under Study

Workstand	Number of workstands	Number of employees
Car tipper operator	6	9
Gantry crane operator	28	41
Comminution process operator	5	14
Fertilizers treatment operator	15	141
Classifying and granulation operator	4	16
Classifying and comminution operator	1	28
Scales operator	1	1
Repairman, welder	3	15
Total	61	180

measurement, all the pertinent variables were carefully checked every two hours, such as flow rate of the air withdrawn, timepiece reading, voltage and current intensity of the power cells. Dust concentration related to one cubic meter of air was calculated from the difference in the filter weights prior to and after sampling with due regard to the volume of the air passed through the aspirator.

Results

The difference in dust concentration between the first and the second half of the workday were appreciable at all the workplaces investigated. A complete characteristic of the particulate contaminants at each workstand cannot as yet be given, on account of insufficient number of the measurements taken. The present preliminary analysis is concerned merely with

average dust concentration at individual workstands during eight hours of the workday (Fig. 2).

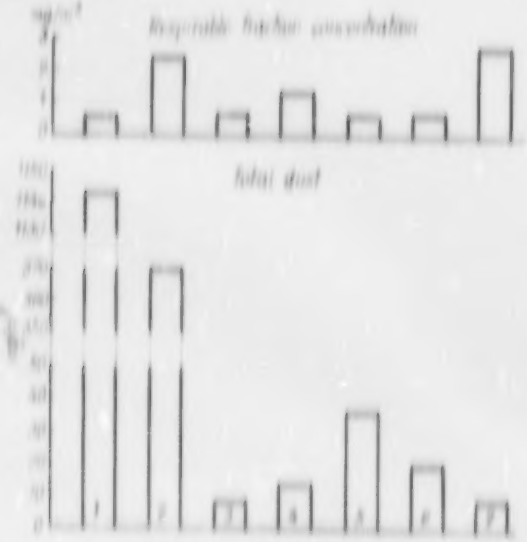

Fig. 2. Average 8-hr dust concentration at the workstands examined: 1 — car tipper operator; 2 — comminution process operator; 3 — pulverulent superphosphate operator; 4 — granuter operator; 5 — screen attendant; 6 — granulated superphosphate transport operator; 7 — welder.

Dust concentration at the workstands examined exhibits a considerable span of values. For total dust concentration it is 7.7–1143.4 mg/m³, whereas for the respirable fraction it varies from 0.02 to 2.74 mg/m³. Noteworthy is the fact that while the differences in dust concentration for total dust were rather remarkable (over 1000 mg/m³), the differences for the respirable fraction were minor (about 2 mg/m³). Here the lack of close correlation between total dust and respirable fraction is manifest. The highest dust concentration (1143.4 mg/m³) was found at the workstand of car tipper operator, but the concentration of respirable fraction there was insignificant in amount to 0.02 mg/m³. At the stand of comminution process operator a high concentration was observed for both total dust (360.5 mg/m³) and respirable fraction (2.04 mg/m³). The workers employed at the transport of pulverulent superphosphate were exposed to a low concentration of total dust (7.7 mg/m³). Despite that low dust concentration in the air the share of respirable fraction was rather high in amount to 0.04 mg/m³. At the place of granulation operator the concentration of respirable fraction was high (1.04 mg/m³) with a relatively low concentration

of total dust (17.4 mg/m³). At the stand of the classifying operator the total dust concentration was appreciable and equaled 35.4 mg/m³, while concentration of respirable fraction was low (0.94 mg/m³). The operator working with the transport of granulated superphosphate was exposed to a somewhat higher dust concentrations than his colleague engaged with transport of pulverant superphosphate. At the stand of granulated superphosphate transport the total dust concentration was 19 mg/m³, whereas for respirable fraction the corresponding value equaled 0.98 mg/m³. Interesting results were obtained for the measurements at the welder workplace, where total dust was low (7.9 mg/m³) but respirable fraction was high (2.74 mg/m³). From the final analysis of the results the data referring to the workplace of gantry crane operator had to be rejected, because the operator used to pour some dust onto the analyser filter. In that case a constant supervision of the sampling was impracticable.

Discussion of the Results

The results obtained have demonstrated the expected correlation between the value of the concentration of respirable fraction of dust and the form of the phosphate stock handled. The finer the stock, the higher the

Table 1

Classification of Workplaces with Respect to the Dust Pollution Level

Concentration of respirable fraction / Degree of pollution	Total dust concentration		
	I (low)	II (medium)	III (high)
I (low)	pulverulent superphosphate operator	classifying (screening) operator granulated superphosphate transport operator	car tipper operator
II (medium)		granulation operator	
III (high)	welder		comminution (pulverizing) operator

concentration of dust respirable fraction and the lower the concentration of total dust (e.g., during the work of pulverizing or granulator operators). Conversely, at the workstands where coarse material was handled the

concentration of respirable fraction was low at a high level of total dust (e.g., car tipper operator).

On the basis of the results obtained, a detailed classification of workplaces could be made as concerns the degree of exposure hazard for the workers to dust of different potential harmful effect (Table 2). The following values were assumed as the lowest limits of harmful concentration: 10 mg/m³ for total dust [9] and 1 mg/m³ for respirable fraction for eight hours. The latter value was taken arbitrarily as no standards in force are available to date. Thus the characteristics of dust hazard could be expressed in terms of a three-step scale:

Average total dust concentration:

I	low	below 10.0 mg/m³
II	medium	10.1–100 mg/m³
III	high	above 100.1 mg/m³

Average respirable fraction concentration:

I	low	below 1.0 mg/m³
II	medium	1.01–3.0 mg/m³
III	high	3.01–5.0 mg/m³

It follows from the classification made that the most exposed to the fine dust hazard are workstands of pulverizing operator and granulator operator. The remaining workstands offer considerable hazard to uncovered parts of the body: skin, eyes and upper respiratory tract. Because in this study the Casella personal dust analyser was used, the data obtained are incomparable with the results of other investigations concerned with the exposure of dust of the crews of workers employed in analogous industries, which were, however, carried out with the use of other apparatus [8], [10], [11].

Conclusions

Even though the results reported here refer to preliminary studies, they could be successfully used in the classification of workstands in terms of individual exposure of workers to the effect of process dusts. With their help a health protection program could be developed by the Hygiene and Safety at Work service for the employees of the plant concerned.

Based on the data obtained a higher incidence can be expected with respect to the nonspecific chronic respiratory illnesses in the group of workers employed in the capacity of operators of such operations as size reduction, classification, granulation, and that of welder.

The dust analyser of that kind is very useful and advisable for the evaluation of the hazard of environmental factors in industry. Obviously, such analysers should be widely used by the plant environmental protection laboratories.

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ASSESSMENT OF THE PERFORMANCE OF THE STOKER-FIRED BOILER EXHAUST CONTROL EQUIPMENT

(Ocena jakości urządzeń odpylających spalin z kotłów rusztowych)

Analysis of the performance and economic feasibility is made for cyclone collectors used on stoker-fired boilers of a capacity ranging from 0.5 to 30 Gcal/hr. On the basis of results of the calculations obtained conclusions are drawn as to further trends in the development of cyclone dust collectors in this country.

For control of the exhausts from stoker-fired boilers with capacities ranging from 0.2 to 30 Gcal/hr, mechanical dry collection devices are widespread in this country, among which cyclone collectors are on top of the list. The following three major equipment groups may be distinguished here:

— cyclones and cyclone batteries formed thereof,

— multiple-cyclones or multicyclones which consist of small-diameter cyclonic elements combined in a common housing,

— Van Tongeren collectors which contain louvered cylindrical concentrators, and in which part of heavily contaminated gas stream is cleaned in cyclones of suitable design.

Occasional use of simple settling chambers will not be of our further interest in this treatment, as such devices are of low collecting efficiency, thus not conforming to the regulations of the protection of natural environment. Likewise, the infrequent cases of experimental application of other emission control equipment have been left out of account in our considerations. In this study as a basis for the assessment of the performance of collection equipment, the overall collection efficiency has been assumed, as that property is closely related to protection of the natural environment. The remaining characteristics such as weight of the device and resistance to gas flow, of lesser significance in that aspect, were given some attention merely in the detailed analysis of selection of optimum cyclone design.

Table 1 provides the data on the cyclone collectors manufactured in this country for the control of flue gases discharged by stoker-fired boilers. For the appraisal of usefulness of individual cyclone types the available results of the measurements performed during the last three years are reported there. The results are arranged according to the cyclone or the boiler type. The listing includes additionally such indices as specific weight of the equipment, inclusive of the dust hopper complete with closure. Reported in Table 1 are also the ranges of the indices obtained related to the moderate-wear condition of the dust control equipment. The data lend support to the belief that is gaining ground among the designers of stoker-fired boilers, viz.,

(a) Van Tongeren collectors should not be used in view of their old and complicated design, as well as their difficult operation and maintaining in full operating efficiency; their collection efficiency may even drop to 87%;

(b) Multicyclones of OMW type manufactured by the Coal Mining Industry Power Assembling Works should be limited in use merely when (for the lack of room) a cyclone battery cannot be installed. These collectors, although to a lesser extent than Van Tongeren collectors, exhibit a drop in collection efficiency below the permissible limit of 80%. As seen in Table 1, their collection efficiency falls even as low as 60%.

From the analysis of the other collection devices reported in Table 1, in the light of the criteria in force, it should be noted that the most efficient and the most stable in operation are cyclone batteries. Their working collection efficiencies average 80 to 90%.

The cyclone batteries set up currently in this country consist usually of the following cyclone types:

— U_{11} and U_{12} designed by the Institute of Thermal Technics in Łódź, designated as type D, in the Dust Collection Equipment Catalog, Vol. I [6];

— CN-15 designed by NIIOGAZ, Moscow;

— OCW and OBW types manufactured by the Coal Mining Industry Power Assembling Works in Chorzów.

The unambiguous selection of the most suitable design from the three cyclone types for the control of exhausts from stoker-fired boilers cannot be made on the basis of the data from testing of operation of these cyclones. The reason for that may be sought in that the operational parameters of these cyclones are not always optimum. The same comparable operating conditions should be used to answer the question which design should be employed. The selection of the optimum design to be used in the future industrial application has been based in this study upon the criterion of the maximum collection efficiency at a minimum cost of the treatment of 1000 m³ per hour of gases. Results of the studies [1] upon which the anal-

Table 1

Values of Radiation Emission Control Device Used for Motor Fleet Motors

Collector type	Overall collection efficiency, η_t, %		Resistance to flow of contaminant through the collector, ΔP, kg/m^2		Specific weight index E_k, kg/(Pa·h)$^{-1}$	Basic type	Reference of measurements	Reference, remarks
	individual measurements	average range	individual measurements	average range				
1	2	3	4	5	6	7	8	9
C_{01}	90.2–91.3		104–105		no data	OKB-5; MCM-5	STC UralVO	
C_{02}	98.8–97.8/98.3		65–77		no data	MCM-227	PG-PM	
C_{03}	92.8		112		no data	MB-4	STC UralVO	[3]
C_{04}	88.0–94.0/91.0; 97.0	95–99	90–95/105–110	40–100	no data	MCM-221	CPKM	
D_4	90.0–95.0		65–90		65–230	—	—	[6]
ЦИОН	90.0–95.0		60–70		no data	MB-3	PG-PM	
ЦС3	95.0–95.0		35–47		200–310	—	—	[5]
СКИЛ	95.0–96.0		55		125–230	—	—	[7]
Аэ-ц-МФ	91.0–99.0		70–75		no data	OM-10	Energoneftemontazh	
Cyclone battery	85.5–92.0; 95.0; 96.0		50–67; 70–90		no data	Stalkonstruktsiya	PG-PM	[4]
Cyclone battery	92.0–95.0		55–65		no data	MB-3	CPKM	
ЦИОН	92.0–96.0; 97.0		60–70; 75		200–300	MCM-Bolero	PG-PM	[5]
СИОН	85.0–77.0–90.0; 96.0	90–95	30.0–42.0; 24.0–35	30–40	no data	OKP	CPKM	
ЦС	92.5–97.0		— —		no data	PCO-40	CPKM	
ЦС	92.0–95		— —		no data	OK-1062-1	Energoneftemontazh	
Intracyclone multicyclone	74.0–78.0; 77.0; 82.7		— — — — —		no data	Stalkonstruktsiya	PG-PM	[4]

Table 1 (continued)

1	2	3	4	5	6	7	8	9
[illegible] collection	59	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Note: IEC — absent — Institute of Thermal Technics; HSzPK — Coal Mining Industry Power Assembling Works; Energomontaż — Power Montering Division Plant; OPKM — Enterprise for Design and Delivery of Air Protection Equipment "OPKM."

ysis is based, refer to cyclones 500 mm in diameter and for air of a temperature of about 20°C (relative humidity 60 to 90%) containing silica flour at a concentration of 5 g/m³. Since silica flour is much finer than fly ash form stoker-fired boilers (particle size for the flour is below 40 μm), the collection efficiency values under large-scale conditions will be more advant/geous as compared with those reported below for laboratory tests. In the preliminary assessment of the performance of the cyclones manufactured in this country, the relation of the cyclone specific weight index W_1 (without dust hopper, hopper closure and other parts independent of the cyclone type) and the relation of the power consumption index, W_2, upon the overall collection efficiency should be determined. Based on results of the measurements given in the study of the Institute of Thermal Technics, these indices are gathered in Table 2 and are plotted in Figs. 1 and 2. The notation of the cyclone types examined and marked on the plots is as follows:

— OC-1 is a cyclone of a diameter D = 500 mm, which is geometrically similar to cyclone of OCW-1100/475 type made by the Coal Mining Industry Power Assembling Works at Chorzów;

— OC-2, as above, but geometrically similar to cyclone of OCW-1100/530 type;

— OC-3, as above, but geometrically similar to cyclone of OCW-1100/600 type;

— CN-15 is a cyclone of a diameter of D = 500 mm, from NIIOGAZ, Moscow;

— C_4 is a cyclone of a diameter D = 500 mm designed at the Institute of Thermal Technics in Łódź and manufactured by ROWENT at Rzeszów as D_4 type;

— CBI — a cyclone developed by BIPROMET at Katowice, and designed for medium and low collection efficiency in paper [3].

The comprehensive index K for annual cost of the treatment of 1000 m³ gas per hour is determined by formula:

$$K = K_1 + \Delta K = K_1 + W_1(C_1 + M + J)\frac{1}{y} + \\ + W_2 8760 \frac{11}{12} C_2 \text{ zł}/10^3\text{m}^3\text{hr}^{-1}\text{year} \qquad (1)$$

where

K_1 — fixed cost of the associated equipment (dust hopper, hopper closure, pipelines, fan platform, etc.) and operation, independent of cyclone type; zlotys/10^3m^{3}hr^{-1} year;

W_1 — specific weight index for the cyclone alone, kg/10^3m^{3}hr^{-1} (Fig. 2);

Cyclone Indices

Table 2

Overall collection efficiency, η_{ov}, %	Indices for Cyclone Types																	
	ЦОТ-1			ЦОТ-2			ЦОТ-3			$C_{ш.1}$			СКН-15			СК$_{ш}$		
	M_c	M_p	Δp	M_c	M_p	Δp	M_c	M_p	Δp	M_c	M_p	Δp	M_c	M_p	Δp	M_c	M_p	Δp
70.0	—	—	—	—	—	—	0.239	72.0	134 130	—	—	—	—	—	—	—	—	—
71.0	—	—	—	—	—	—	0.264	69	149 154	—	—	—	—	—	—	—	—	—
72.0	—	—	—	—	—	—	0.301	65.2	168 174	—	—	—	—	—	—	—	—	—
73.0	—	—	—	—	—	—	0.336	59	198 208	—	—	—	0.165	61.1	1504 —	—	—	—
74.0	—	—	—	—	—	—	0.415	56.5	248 257	0.199	62.5	979 —	0.21	62.2	1640 —	—	—	—
75.0	—	—	—	—	—	—	0.496	50.0	278 311	0.2	73.5	1007 —	0.264	70.1	1880 —	—	—	—
76.0	—	—	—	—	—	—	0.602	47.1	356 362	0.272	68.1	1296 —	0.329	68.5	2061 —	0.222	63.7	1977 —
77.0	0.229	47.5	279 286	0.202	66.5	988 1021	0.705	39.9	398 397	0.33	61.2	1760 —	0.397	63.5	2231 —	0.192	51.3	1534 —
78.0	0.274	45.1	340 338	0.239	64.5	1178 1215	—	—	—	0.405	23.5	1685 —	0.469	58.2	2474 —	0.45	42.5	1979
79.0	0.279	45.2	342 340	0.466	55.2	1257 1300	—	—	—	0.554	48.3	1729 —	—	—	—	—	—	—
80.0	0.429	73.0	575 548	—	—	—	—	—	—	0.545	43.8	2762 —	—	—	—	—	—	—
81.0	0.512	44.0	1018 1005	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Service life, T, years, after PPC [3]	4.25			11.5			39			4			11			4		

The upper value Δp refers to the price of a ЦОТ-КЕМТ cyclone, C_c = 71.5 dollars/kg, the bottom one, to the price charged by the Assembling Works, C_c = 50 dollars/kg.

Dimensions of the values are: $[M_c]$ years/(Pa^2·m^3); $[\Delta p]$ dollars/(Pa^2·m^3·s^{-1}); $[M_p]$ kg/(Pa·m^3·s^{-1})

W_e — electric power consumption index, kwhr/10^6m^3, calculated for a fan efficiency of 70%/s (Fig. 1);

C_1 — price of one kilogram of cyclone weight, assumed as the arithmetic mean from the maximum and minimum weight for the equipment delivered by ROWENT, C_1 = 71.5 złotys/kg;

M — cost of the assembly of a cyclone with the margins (taken on the average as 3000 złotys/ton);

I — cost of thermal insulation of a thickness of 100 mm together with rust-proofing of the cyclone (assumed on the average as 50 złotys/kg of cyclone weight);

T — service life of the cyclone according to the testing of the Institute of Thermal Technics, Łódź [1] was taken in conformity with Table 2;

C_2 — price of electric power (assumed on the average as 0.51 złotys/kwhr for the plants subordinated to the Ministry of Mining and Power);

ΔK — the total cost of dust collection from 1000 m^3 gas/hr which depends upon the cyclone type.

The costs of emission control calculated with the aid of formula (1) are gathered in Table 3 and illustrated in Fig. 3, in which fixed costs K_s were assumed as the reference, independent of the cyclone type. For cyclones manufactured by the works in Chorzów additionally the curves are marked (broken lines) which correspond to the present sale price of cyclones charged by that company, and which amounts to 80 złotys/kg. As can be seen from the plot, this is a critical factor for the selection of the optimum cyclone design.

On the basis of the relations of indices W_e, W_c, ΔK and total collection efficiency (presented in Figs. 1, 2, 3), the following conclusions can be made:

(1) When high collection efficiencies are required, the most economical is cyclone of OC-1 type from the Coal Mining Industry Power Assembling Works. Thus it appears desirable to elaborate specifications for a new series of high-performance cyclones of diameters ranging from 100 to 1000 mm which will be geometrically similar to OCW-1(100/475 cyclones with subsequent putting on stream their commercial production.

(2) For medium collection efficiencies the most advantageous are cyclones of OC-2 type manufactured by the Assembling Works mentioned in point (1) which, even at the sale price charged by ROWENT, yield somewhat lower emission control costs than with the use of cyclones of D, type. In this connection specifications and production are to be developed for medium-efficiency cyclones that are geometrically similar to OCW-1(100/550 cyclones with diameters from 400 to 1000 mm. The cyclones in point would have the same shells as the high-performance cyclones mentioned

in point (1), differing merely in the outlet pipe. Maximum standardization could thus be achieved as concerns inlet ducts, supporting structures, and dust hopper complete with fittings.

(3) For collection efficiencies needed, the lowest emission control costs can be attained with cyclones of CH1 type which are now not manu-

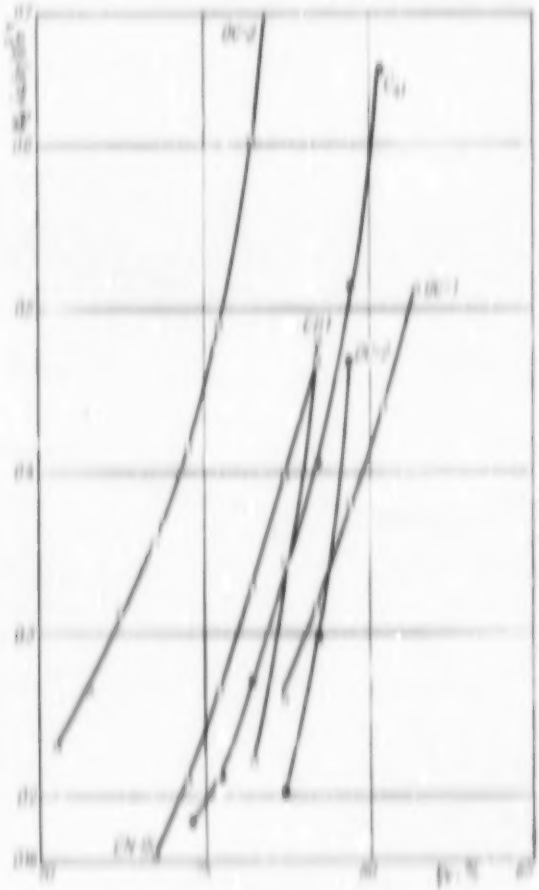

Fig. 1. Relation electric power consumption W_e vs. overall collection efficiency η_c for various cyclone types.

factured in this country. For such purposes cyclones of D, type still will have to be used. If production potentialities of the Assembling Works are available, priority should be given to OCW-1100/530 cyclones and the OBW batteries set up from the latter.

(4) The least economically sound are cyclones of MC-8 and CN-15 types which should not be used in the future emission control installations.

(5) The course of the curve for relation electric power consumption vs. overall collection efficiency (Fig. 1) lends support to the theoretically proven conclusion in [2] that cyclone C_{11} and its derivative types C_{11} and D,

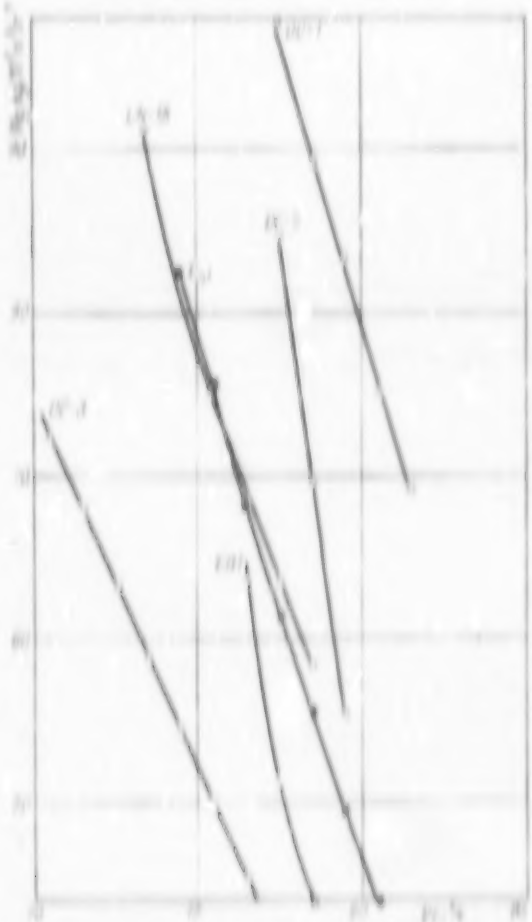

Fig. 9. Relation specific weight index W_g vs. overall collection efficiency η_0 for various cyclone types.

are not of the optimum design, unlike the cyclones made by the Assembling Works and CBI cyclone.

Moreover, to improve the emission control technique in the treatment

of flue gases discharged from stoker-fired boilers, the following undertakings should be accomplished:

— The outlet collectors of OBW batteries composed of UCW type cyclones, discussed at points (1) to (3), should be redesigned in the fashion the collectors of the CN-15 battery are devised, so as to make use of the

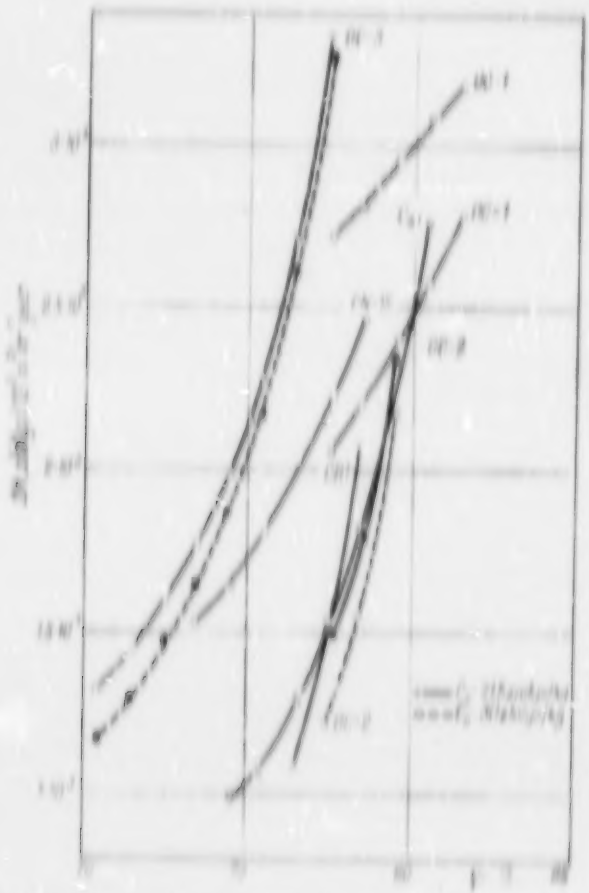

Fig. 4. Relation variable component of cost (K of treatment of 10^6 m^3/h flue gases vs. overall collection efficiency η_c for various cyclone types

kinetic energy of the swirling gas stream leaving the outlet pipe. Owing to this, the efficiency of cyclones made under the licence of Walter company would be remarkably increased over the KOWENT [illegible], cyclones included in the KLIMA-WENT, Katowice, catalog.

— Steel grades St3 used in the production of cyclones should be replaced by the grades of increased strength and abrasion resistance, e.g. 20HGSi grade;

— Van Tongeren collectors should be abandoned in the control of flue gases from stoker-fired boilers, as these devices are of complicated design and difficult to maintain in full operating condition;

— Multicyclones of OMW type should be used only in cases of restricted space for the installation of a cyclone battery. Even less bulky than OMW multicyclones, direct-flow multicyclones developed at the Institute of Thermal Technics in Łódź, are not recommended for use prior to substantial changes in the design and without encouraging results of service testing.

— In the specifications for typical emission control systems of TIO type for boilers of WCO, PCO, OKR, WR, WLM, and PLM types (WOBP sheets Nos. 1.2.1. through 1.2.11) developed by BISTYP Research and Designing Center of Industrial Building in Warsaw, the cyclones of C_{11} and C_{12} types used there should be substituted with those geometrically similar to OCW-1100/530 cyclones with redesigned outlet collector in accordance with point (1);

— Special attention should be given to maintain in full working condition the equipment of the emission control house and boilerhouse to ensure proper service of the emission control system. In particular the following should be borne in mind, namely:

(a) combustion process should never proceed with not enough air, as otherwise the carbon black generated fails to be precipitated in the cyclones but is wholly released into the atmosphere;

(b) maximum possible tightness of dust hopper should be ensured, similarly to the seats between hopper and the cyclone, and between the cyclone and the flue and fan;

(c) maximum permissible dust level in the hopper should never be exceeded, and the hopper itself should be periodically discharged;

(d) correct operation of the dust closure of the hoppers;

(e) good condition of thermal insulation, so as not to permit the dew point be locally surpassed, with a subsequent premature corrosive wear of the emission control devices.

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Retyler, A.

THE INFLUENCE OF URBAN AND INDUSTRIAL AREAS UPON THE LOCAL CLIMATE

(Wpływ terenów zurbanizowanych i uprzemysłowionych na klimat lokalny)

Attention was called to the thermal phenomena which are the most essential factors shaping the climate, particularly local climate.

In recent years many papers have been published on the problem related to the influence of economic activity of man on variations of climate on a global scale. The authors of those papers focus their attention on two major sources of such variations, namely: atmospheric pollution largely with combustion products, and heat release in the manufacturing and power generation processes. A number of concepts and ideas are set forth as to the influence of individual atmospheric pollutants upon the radiative and thermal balance of the Earth's surface, as well as those concerning the changes that occur for instance in the hydrosphere as affected by some factors that globally enhance or attenuate the original effect [1], [3].

Considerations expounded in this work will deal with the influence of man's activity on local climate alone, where another critical factor is also that of the transformation of the original terrain surface. Atmospheric pollution and release of thermal energy in the manufacturing processes appear to be here perhaps more evident reasons for the climate variations. Attention will also be paid to thermal phenomena which are obviously the most vital factors in the shaping of every climate, including naturally also local climate. It seems therefore necessary to define the concept of local climate.

By local climate will be meant the climate of any spot or area which is shaped by thermal or dynamic processes, or both, which are determined by the Earth's surface entities of local significance. Cities or larger urban or industrial areas (like, e.g., the Upper-Silesian Industrial Region) are

the examples of such independent, though artificial, entities of the Earth's surface. The urban and industrial areas henceforth will be referred to for brevity as simply urban areas or simply the city.

The urban areas feature obviously a number of particular properties of the surface, which makes them clearly distinct from rural areas. More important of those are a great effective surface, considerable thermal conductivity, and insignificant ability to retain the precipitated or thawing waters.

The first two factors favor a great accumulation of heat in the urban surface, owing to which it can give off more heat to the air. The effect is particularly evident in the absence of the inflow of solar energy — that is, in the evening and nocturnal hours. Considering the last property of urban surface, solar energy participates to a greater extent in the turbulent heat exchange as compared with rural areas, since this heat is not as much used up for evaporation process, operative in the latter.

Still another factor can hardly be left out of account, even though it is not so directly connected with urban surface, namely, the hindered air flow inside urban areas. It will be worthwhile to mention here, after McCormick [7], results of the studies by Munn (1968). That investigator reports that in cities windspeed falls approximately to two thirds of the windspeed observed in rural areas. Thus, a climatologic property of the city is a weaker air exchange, owing to which the air temperature is higher there relative to rural areas.

The above conclusions make one believe that both in the daytime and at night the air in and over city is warmer than on the undeveloped regions. Rather remarkable are in that aspect the studies made by T. R. Oke et al. [16] carried out in a summertime period some 30 km south of Vancouver. The studies have demonstrated that the turbulent heat streams in the daytime, as measured 1 and 4 m above the surface of the roof of a four-story building situated within the city, had higher values than those measured 2 m above grass at Ladner.

Special emphasis should be placed on the fact that during nocturnal hours, according to the studies, a turbulent heat flow from the surface to the air was maintained (Fig. 1) over the urban area. On the other hand, at a height of 4 m the direction of heat flux used to change the sign a few times during the same night. Simultaneous study made with an instrument of a special design with a heat-exchanging surface of a block made of concrete, gravel, and asphalt furnished sufficient data to establish that the values of heat fluxes in the urban surface are also higher than those in the soil of rural areas.

The measurements taken on two successive days following a heavy rain shower, furnished some other interesting data. Specifically, the next

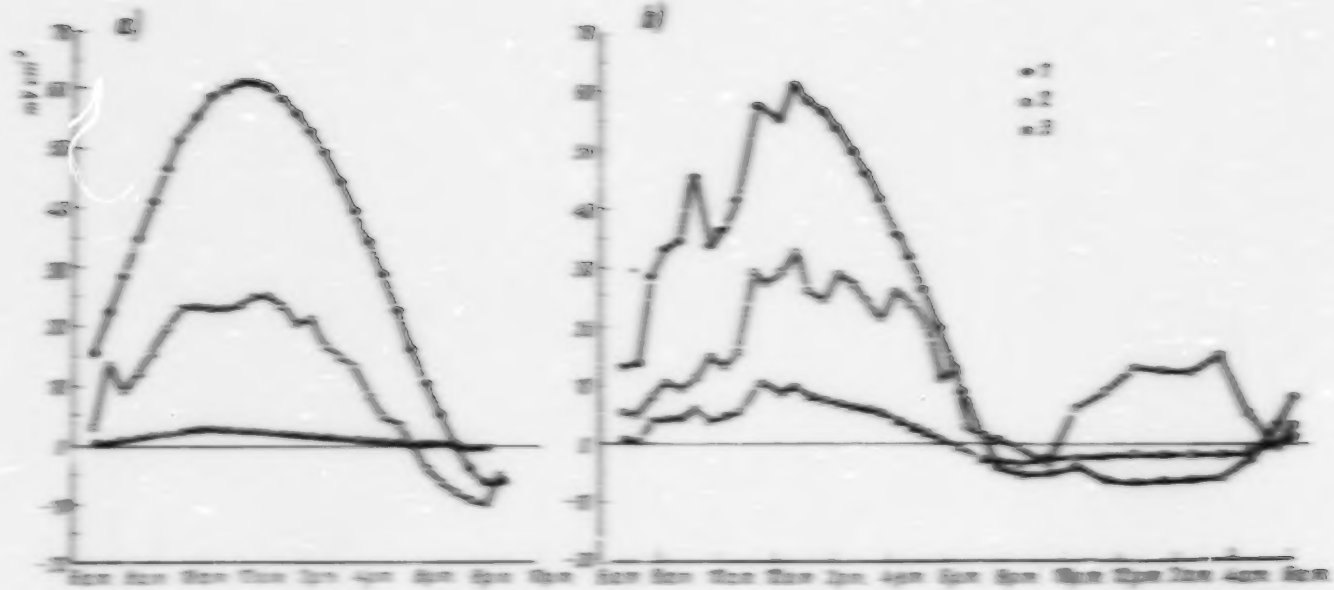

Fig. 1. The course of certain components of thermal balance measured: (1) in above the roof surface; a — at Leningrad, on July 1, 1972; b — in Tashkent, on July 2128, 1972; 1 — total radiation, Q; 2 — turbulent heat fluxes, P; 3 — value of heat exchange in the ground, G).

day after the shower, the absolute values of the heat used up for evaporation of water from the roof surface were much higher than the values of the turbulent heat exchange. On the subsequent day the proportions drastically changed and in the heat balance the nonlatent heat given up into the air took clearly over.

The studies in point, however, were of a preliminary and incomplete nature. Another factor to be given due regard to is the effect of decreased values of the global total solar radiation by pollution of air largely with particulates on the prevalent thermal conditions on the urban and industrial areas. Landsberg reports that the reduction of total radiation in cities reaches 15 to 20% [14]. In summertime in Cracow this value equals about 10 to 15% according to Olechi [11]. It is also believed that the presence of airborne pollutants over city results in decreased effective radiation, which may be of significance merely at night. The influence of these phenomena upon thermal conditions should not, however, be overestimated, which may be confirmed by some of the data taken from the study due to Krsujalis [8]. Specifically, the ratio of the quantity of artificial heat (in Kcal $cm^{-2} sec^{-1}$) emitted into the air during the manufacturing and power generation processes, to the sums of the total radiation and effective radiation, equals for Bytom ca. 39 and 94%, for Świętochłowice ca. 78 and 187% and for Chorzów ca. 83 and 198%, respectively. Even though the comparing of the two quantities is a fairly formal measure, it still affords a general idea of the prominent role played by artificial heat in the shaping of the climate of cities.

The combined effect of the factors mentioned above results in the formation over urban areas of so-called urban heat islands. The properties of this phenomenon are particularly visible under conditions of free nocturnal radiation (clear sky, faint winds).

Deeper understanding of the vertical and horizontal structure of heat islands can be made on inspection of Figs. 2, 3, and 4. The following four properties of this structure deserve special attention, namely:

(1) The highest air temperatures occur commonly in the middle sections of cities; moreover, the greatest horizontal temperature gradients are observed upwind of those sections (Fig. 2);

(2) Upper boundaries of the urban heat islands are at the same time the lower boundaries of isothermal region or of upper inversions;

(3) In the warm air layer, referred to as urban boundary layer, adiabatic or superadiabatic temperature gradients occur (Fig. 4), while in rural areas temperature inversion is observed;

(4) Transfer of heat together with air pollutants takes place into the strictly urban area (Figs. 2, 3, and 4).

The intensity of certain phenomena discussed as well as the value of the thermal differences observed between city and the rural area (ΔT_{u-r}) is inversely proportional to the value of the immersion and windspeed (7).

The appearance of fog exerts a serious effect. Its presence results in such variations as more pronounced upper inversion over city, whereas in the urban boundary layer the adiabatic temperature drop is replaced by isothermal distribution.

Under conditions of unrestricted nocturnal heat radiation (no clouds), intensity of the phenomena that determine the heat island (as in point (1)

Fig. 8. The temperature distribution, in °F, in Austin, Texas, on February 4, 1974, at 9:00 a.m. local time.

to (4)) and the city-countryside thermal differences (ΔT_{u-r}), depends upon the size of the heat sources in the city, temperature gradient in the planetary boundary layer upwind of the city (favorable heat balance index) and the windspeed within that layer (7).

Fig. 3. The temperature distribution, in the lower friction layer over Cincinnati, O., on May 24, 1937, lower windspeed 3 miles; solid line denotes the upper limit of the urban boundary layer, broken line refers to the layer-wise discontinuity lim-

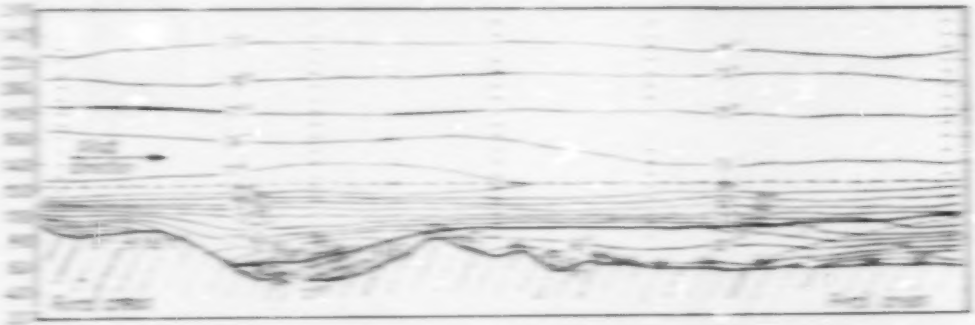

Fig. 4. The temperature distribution, in °F, in the surface friction layer over Cincinnati, O., on July 31, 1937, surface wind-speed <1 mile; the lines are denoted as in Fig. 3.

As not all the relationships have been sufficiently well learnt and evaluated, merely some of them have been treated at greater length.

According to the studies by Oke and East, the height of the urban boundary layer over large American cities averages from 200 to 300 m [10]. Generally, with increased windspeed the height of the urban island becomes larger (Figs. 3, 4), and the difference in the air temperature (ΔT_{u-r}) decreases. The pertinent relations are not linear. Linear is, on the other hand, relation (ΔT_{u-r}) vs. temperature gradient in the planetary boundary layer. Ludwig and Kealoha demonstrated a close correlation of the two quantities, a correlation coefficient being 0.90. The nature of the above correlation, according to Summers, consists in that heat accumulation in city occurs in the air flowing through the city from rural areas (cited after [7]).

The phenomenon mentioned under point (4) was determined and named by Clarke who has given it the name of urban heat island [9]. Along with the heat also gaseous and particulate emissions are transported over rural areas, which exert a joint effect on the climate there (altered thermal balance, etc.). Thus the zone of the influence of the city upon the local climate extends over its limits, in a way approximately shown in Figs. 2, 3, and 4. The size of that zone and the intensity of the phenomena that occur there depend upon the climatogenic factors of the city, climate, and physiographic conditions (primarily surface relief).

With reference to the Upper-Silesian Industrial Region (USIR) the spatial picture of the phenomena under consideration is undoubtedly highly differentiated and involved, as at least each of the thirteen large cities located there generates its own heat island [9] and its own zone of influence that mutually overlaps with the adjacent ones. Viewing the USIR as a whole, one could therefore speak of one huge heat island. This would not be right, however, on account of a highly limited in time (only with high winds) flow of fresh, cool air from rural areas through the cities located in the middle of the conurbation.

According to Kruczala [8], within the USIR heat island the usual effect of sea-level altitude on air temperature, thickness and stability of snow cover, and total precipitation, has been disturbed, let alone the changes in their absolute values compared with the peripheral regions.

A vast number of investigators were for long making attempts to find a correlation between the city size and the rise in the air temperature relative to the rural areas. The notion of city size should be understood as a body of factors which are typical of that city, and which bring about joint variations in the nature and quantity of the energy-related processes that occur within it. The factors have been broadly defined earlier in this article. The difficulty involved in the study on the relations be-

tween the city size and the rise in the air temperature compared with the rural areas lies in the comprehensive approach to these factors and their expression in terms of preferably one characteristic quantity which well correlates with those factors.

The studies discussed above combine investigations on the mutual effect of climatogenic urban factors and the macroclimate, inclusive of the local climate of a given area. Together with other studies (largely concerned with the vertical structure of heat islands), they are of value for regional and urban development and environmental engineering practice, being useful in the field of climatology and meteorology of urbanised areas.

The question of studies on the size of the urban heat island, meant here as the temperature difference of air in the city and in the rural areas, was originally viewed in the aspect of the influence of the development of the city upon the air temperature within its limits (Arakawa, 1937; Fukui, 1957; Mitchell, 1961). A difficulty involved in those studies consists in the necessity to eliminate the climatic changes occurring in the period of the city development. In 1956 Kratzer set forward a concept of the existence of a correlation between the city size and the size of urban heat island, expressing arbitrarily the city size in terms of the number of its inhabitants.

A remarkable relation between the city-rural area temperature difference and the number of inhabitants of the city has been reported by Ludwig (1970). The relation is deduced for nocturnal conditions of very light cloudiness, and it has the following form

$$\Delta T_{u,r} = P^{0.17}/4.04\bar{u}^{0.53} \cong \sqrt[4]{P}/4\bar{u} \qquad (1)$$

where

P — the number of inhabitants,

$\bar{u}$ — the average windspeed in the rural area.

The above relation has a correlation coefficient $r^2 = 0.71$ and a standard error $E_{\Delta T} = \pm 1.6°C$.

On the assumption that the city is a uniform heat source, according to Summers (1964), $\Delta T_{u,r}$ is proportional to the square root of the radius of the city area, and this quantity in turn is proportional to the square root of the area of urban development. Since the number of inhabitants is proportional to the city area, Tobler (1958) found a close correlation between the area of North American cities and the number of their inhabitants ($\Delta T_{u,r}$ should be roughly proportional to $\sqrt[4]{P}$; cited after [9]).

The above formula is reported here in view of their versatility (at least with reference to North American cities), in spite of the not the highest correlation coefficient and a comparatively large standard error.

Other correlations of that kind have higher correlation coefficients and lesser standard errors. An example of these may be here the relation illustrated in Fig. 5 and deduced by T. R. Oke [8] for ten Canadian cities situated in the St. Lawrence Lowlands. In setting up that relation the highest temperatures measured every night over the city area were taken. For comparison Fig. 6 shows the dependence of the absolute maximum

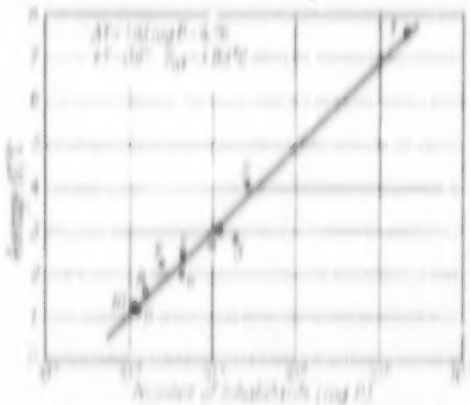

Fig. 5. Eleven-night average air temperature difference in cities and in rural areas as a function of the number of inhabitants of the cities in the St. Lawrence Lowlands, Canada: 1 — Montreal; 2 — St. Hyacinthe; 3 — St. Hubert; 4 — Chambly; 5 — Marineville; 6 — St. Basile-le-Grand; 7 — St. Cesaire; 8 — St. Pie; 9 — Ste-Angele-de-Monnoir; 10 — Ste-Madeleine.

air temperature difference for the urban and rural areas and the number of inhabitants of the cities ($\log P$). The cities under consideration are located in substantially different climatic conditions, which would suggest that relations of that kind may well be used for the evaluation of ΔT_{u-r} in other areas. The matter is not, however, so simple and straightforward. For a given city size (P), the maximum air temperature differences (ΔT_{u-r}) are for instance in Western Europe lower than in North America despite that in European cities far more considerable air temperatures modifications should be expected in view of a higher population density (Fig. 7). In Europe ΔT_{u-r} is proportional to $\sqrt{P}$ (Tubler, (1969).

Oke [8] argues that the reason for that phenomenon may be sought in lower values of the heat fluxes originating from artificial emission sources, or in higher evaporation values in European cities. It seems, however, that irrespective of the former reason on which hardly anything specific can be said, this phenomenon should be linked with higher values of humidity and moisture of the air and ground surface in Western Europe

These latter factors control the quantity of the effective loss of heat by radiation, which is responsible for the air cooling rate, largely in rural areas (author's note). Ludwig (1970) observes that the size of the urban heat island depends to a large extent on cooling process in the rural areas that surround the city (cited after [10]).

Evidently, the appraisal of the correlation of the urban and climatic factors which determine the size of heat island is difficult on account of incomplete comparative studies available (e.g., as above), and because P index defined in terms of the number of inhabitants is not clearly and precisely defined.

Some investigators openly argue [9] that essentially no correlation exists between ΔT_{u-r} and the number of inhabitants. Thus some other physically determined quantities must be sought. Coming back to the idea of investigations in Vancouver and Ladner, that correct physical quantity should be the value of heat balance of the city. Subsequently, relations should be looked for to correlate this quantity with the parameters determining physical character of the city. Such studies are, however, impracticable as yet.

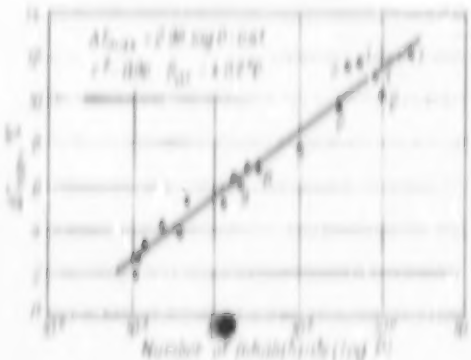

Fig. 6. The maximum air temperature differences T_{max} in the cities and their neighbouring rural areas vs. the number of inhabitants in North America: 1 — Montreal; 2 — Vancouver; 3 — San Francisco; 4 — Winnipeg; 5 — Edmonton; 6 — Hamilton; 7 — San Jose; 8 — Palo Alto; 9 — Corvallis, black points denote cities and settlements of the Quebec province.

Up to this point attention was being paid to the air temperature differences which are representative of nocturnal radiative type weathers. It will therefore be of interest to present on that background the mean annual air temperature differences for urban and rural areas.

Landsberg (1960) and Chandler (1966) report that mean annual air

temperatures in large cities (above 100 thousand inhabitants) are higher by about 0.6 to 1.3°C from the analogous temperatures in rural areas (cited after [7]). The value of this increment of the air temperature relative to the neighboring areas for Cracow fits perfectly to that range, being 0.9°C in the period from 1954 to 1968 [4].

To realise the significance of the effect of a city, similar in size to Cracow, upon thermal climate, it seems worth noting that starting from

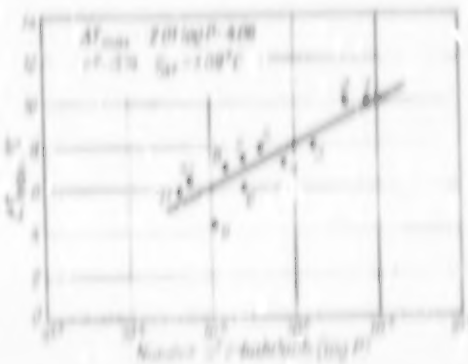

Fig. 7. The maximum air temperature differences in the cities and their neighboring rural areas vs. the number of inhabitants of the cities (Western Europe): 1 — London; 2 — Berlin; 3 — Vienna; 4 — Munich; 5 — Sheffield; 6 — Utrecht; 7 — Malmö; 8 — Karlsruhe; 9 — Reading; 10 — Uppsala; 11 — Lund

the altitude of about 500 m above sea level in West Carpathians the air temperature differences on convex and concave (bottoms of valleys) forms are greater than in Cracow (220 m above sea level) and its surroundings. Mean annual air temperature difference on the topographic forms mentioned at a level of 220 m above sea level amounts to 3 more 0.3°C. Only the effect of the great and deep valley, which is the Dunajec valley near Maniowe, on thermal conditions there results in that the mean annual air temperature difference at the bottom of the valley is lower by 0.9°C from the temperature observed at its corresponding altitude above sea level on a convex form [4].

In the annual course, the distribution of the air temperature differences between city and rural area depends upon the climate. In a series of West European and American cities the size of heat islands is greater in the summer and early fall than in the other seasons [9]. For the cities of Central Europe a more even air temperature differences are typical in the annual course [13], which is due to a significant energy consump-

tion" in wintertime. A clear shift of the largest (ΔT_{u-r}) differences should be anticipated in the fall-winter period on the areas of the North (e.g., in Europe) with a well defined continental properties of the climate. This is due to a considerable energy consumption for residential heating, and appreciable values of effective irradiation in the dry and cold continental air. Conversely, in humid subtropical climates the air temperature differences in cities and their adjacent rural areas should be insignificant and equalised over the year.

In the diurnal course the highest intensity of heat islands is noted in the evening and nocturnal hours; the lowest one, on the other hand, is observed during the day on account of enhanced air mixing processes. The difference in mean minimum temperature for London and Washington equals about 2.0°C [9]. The comparatively great difference in the minimum temperature of the air for Cracow (1.6°C) compared with the one reported above may result from the location of that city in the Vistula valley.

For diurnal hours, in default of other data, the value of the maximum air temperature for Cracow may be quoted here. The value amounts to a mere 0.1°C [4]. It appears that even for the cities much greater in size no significant differences should be anticipated here.

In conclusion it should be said that such remarkable thermal differences in favor of urban areas and the specific processes occurring in them result also in substantial changes of other climatological elements.

Conclusions

(1) In connection with the progressing urbanisation of this country and with the changes in the natural environment, comprehensive research should be conducted on the effect of the city upon local climate. The main effort should be focused on the investigation of the vertical structure of heat islands (dispersal of atmospheric emissions) against the background of the climatic conditions of a given area and of the thermal balance in the city.

(2) One of the major questions in that research is the expression of the city size in terms of a physically sound index or indices as a function of the urban climatogenic factors (surface building-up, heat sources, atmospheric emission rate).

(3) The city size index in use now — that is, the number of inhabitants, is not unequivocally determined and clearly substantiated physically. Nevertheless, its relation to the thermal conditions prevailing in the city is measureable and fairly useful.

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POLEMICS

Calculation of the Emitter Parameters

Recently [1] a polemic article has been published on the calculation of the optimum, in terms of air pollution control, emitter parameters. The problem touched upon is of significance in the field of air pollution control. However, in the article in point it has been limited to a single emitter of a definite height and of low capacity, which operates on the area where the background concentration can be assumed as constant. Generally in practice much more complex situations arise, which cannot be handled with the method of calculation of the emitter parameters set forth by Nowak [1].

In order to determine the optimum parameters of an emitter to be built on a constant-background area, in the first place the maximum pollutant concentration $S_{\max}^{i}$ ($i = 1, 2, 3, \ldots$ denotes individual pollutants) should be found, which are emitted by that source with a given weather type. Denoting by $S^{i}(x, y, z, w, H, P, T)$ the function determining the concentration value of the pollutant of ith kind at the point (x, y, z) of the space due to a stack of a geometrical height H and of the performance characteristics T at a windspeed w blowing from the direction $+x$ under weather parameters P, the above task resolves itself into the solution of a set of equations

$$\partial S/\partial x_i = 0, \quad x_1 = x, \quad x_2 = y, \quad x_3 = z, \quad x_4 = P \qquad (1)$$

Assuming the weather parameters in accordance with the pattern suggested by Sutton, solution of set (1), for a definite type of the atmospheric stability determined by coefficient n, ($0 \leq n \leq 0.5$), affords the following expression for the maximum concentrations $S_{\max}^{i}$

$$S_{\max}^{i} = \frac{Q_i \left(1 - \frac{n}{2}\right)^{2-1} w^{n-1} \beta_i}{2\pi e A} \cdot \frac{(1 - \gamma)n}{2 - n} \cdot H^{-\frac{2(1-n)}{2-n}} \qquad (2)$$

It is noteworthy that formula (2) yields the maximum concentration with due regard to variable windspeed w.

The above formula was derived on the assumption that windspeed $u(H)$ at the geometrical height H of the emitter, may be replaced by the average value

$$u(H) = \frac{n}{H}\int_0^H \left(\frac{z}{z_1}\right)^{0.5} dz = \left(1 - \frac{n}{3}\right)\left(\frac{H}{z_1}\right)^{0.5} w \qquad (3)$$

The symbols appearing in formula (2) and (3) denote as follows: Q_i — the emission of pollutants of the ith kind, w — windspeed at a height z_1 (the height of the anemometer used), and A — a term connected with thermodynamic superelevation.

In case of medium-capacity emitters, thermodynamic superelevation is well described in terms of Holland's formula, and then

$$A = D(1.5 + 0.01\Delta T v) \qquad (4)$$

and $\gamma = 1$.

The notation of symbols in formula (4) is analogous to that in (1) — that is: D — emitter diameter, v — velocity of the waste gases from emitter, $B = 3.10 \times 10^{-3} c_p \gamma_0$ (where c_p — specific heat and γ_0 — specific gravity of the waste gases), ΔT — the temperature difference for the outlet waste gases and the ambient air in the surroundings of emitter, $1.1 \leqslant \beta \leqslant 1.5$ for labile atmosphere and $0.8 \leqslant \beta \leqslant 0.9$ for a stable atmosphere.

It follows from the above that for medium-capacity emitters

$$\frac{S_i}{S_i'} = \frac{Q_i}{3w_0 D_0 \beta(1.5 + 0.01\Delta T)} \frac{1}{H} \qquad (5)$$

where S_i denotes the concentration of the ith kind pollutant allowed by the standing regulations.

Since

$$Q_i = \frac{\pi D^2}{4} v s_i \qquad (6)$$

where s_i signifies the number of grams of the pollutant of the ith kind in a unit volume, therefore the condition determining the optimum emitter parameters is as follows

$$H_i = \frac{f(H, D_i)}{3w_0 D_0 \beta(1.5 + 0.01 H_i \Delta T) S_i'} \qquad (7)$$

In the above formula $f(H, D_i)$ determines the relation between the exit diameter of the stack and its geometrical height. This relation results from conditions of the design.

It can be seen from formula (7) that a design on the safe side of a medium capacity emitter necessitates merely the determination of its maximum geometrical height and, accordingly, of its diameter as a function of product $A_1 B_1$. In case the emitter under design is to have a capacity of a few hundred megawatts, the thermodynamic superelevation is evaluated from the Concawe (C) or optimized Concawe (OC) formulas. Under these circumstances term A and exponent γ that appear in formula (2) are as follows

$$A_1 = 0.175 Q_1, \quad \gamma_1 = \frac{3}{4} \tag{8}$$

or

$$A_{1'} = 0.414 Q_1^{0.444}, \quad \gamma_{1'} = 0.694 \tag{9}$$

where Q_1 denotes the heat emission by the stack.

Thus, to determine the optimum parameters of such an emitter the complex formula (2) must be used. As follows from that formula, the parameters in case of high-capacity emitters depend more on the type of atmospheric stability than the parameters of medium-capacity stack do.

The determination of optimum parameters of a single emitter becomes additionally more complex if it discharges, apart from gases, particulates of a diameter above 20 μm. Then an analysis similar to the above should be also made for the function of the dust fall. Thus, it can be said that the evaluation of the optimum parameters of an emitter under design is a complex problem even for a single emitter operating on an area of a constant background. In practice, however, the situations encountered are still more involved. Notably the new emitter designed will be operative in the area where the pollution level is already determined by a vast number of other active emitters. Then the background — that is, the overall air pollution due to a large number of the existing emitters is typically a rather complex function of the site, and the analytical solution of the problem of determination of the optimum emitter parameters becomes unfeasible.

An instance of this may be an emitter designed to operate not far from another operating emitter. As shown in [3], even in that case an analytical expression for $H_{1,2}$ for the two emitters cannot be found. The only way out is to resort to numerical techniques and calculations with computers. The methods of estimation by that approach of the optimum parameters of many emitters simultaneously or of a single emitter designed

for an area where the air quality is already affected by a large number of other emitters, have been given in [3]–[5].

Prepared by Assistant Professor K. Wojciechowski

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INDUSTRIAL BRIEFS

Cooperation between the Polish People's Republic and the Czechoslovak Socialist Republic in the Field of Air Conditioning Ventilation and Emission Control Equipment

The common projects under the bilateral economic, scientific and technical cooperation between the KLIMA-WENT Industry Branch and its corresponding foreign partners from the socialist countries are being accomplished by Working Groups entrusted with the ventilation, air conditioning and corrosion control technology.

In the accomplishment of the resolutions of the intergovernmental cooperation bodies, the Working Groups work out and establish the program for economic cooperation that includes exchange of goods, cooperation and specialization of production, and scientific and technological cooperation.

The detailed and fragmentary problems within the framework of the Working Groups activity are entrusted to Expert Groups.

On such principles the KLIMA-WENT Industry Branch cooperates with the following countries:

— the Czechoslovak Socialist Republic,
— the German Democratic Republic,
— the People's Republic of Bulgaria.

Each of the Working Groups has its peculiar, suitably formed and elaborated methods of work. Here some attention will be paid merely to the question of cooperation with the Czechoslovak Socialist Republic.

The Ventilation, Air Conditioning, and Emission Control the Polish People's Republic — the Czechoslovak Socialist Republic Working Group was called into existence in 1971. Its organizers and cooperators are the following entities:

— on the part of Poland — KLIMA-WENT Industry Branch, Katowice,

— on the part of Czechoslovakia — Ceskoslovenske Vzduchotechnicke Zavody, Generalni Reditelstvi, Praha

In the course of time, within the framework of the Working Groups the following Polish-Czechoslovak Expert Groups have been called into existence:

- Fan Expert Group,
- Air Conditioning and Ventilation Group,
- Emission Control Group,
- Scientific and Engineering Cooperation Group.

Owing to regular meetings of the Working Group with the Expert Groups (in principle twice a year) the following work has so far been accomplished:

(a) preparatory and organizational work, including:
- organization of Expert Groups and setting the scope of activities,
- programming of work,
- subject matter for the meetings,
- frequency of the meeting, etc;

(b) market research as concerns demand and supply with reference to the ventilation, air-conditioning, and emission control equipment;

(c) exchange of catalogs and leaflets on the equipment and installations;

(d) preparing the list of equipment and installations for specialization;

(e) preparing draft specialist agreements and contracts in the field of such technologies as:
- fans,
- air-conditioning,
- emission control;

(f) organization and sponsorship of the symposium of the ventilation and air-conditioning equipment manufactured in Czechoslovakia, held in 1974, in Warsaw. Mention should be made here that a total of 150 specialists took part in that symposium, representatives of nearly all the designing offices in Poland;

(g) organization and sponsorship of the symposium on the ventilation, air-conditioning, and emission control systems manufactured in Poland, largely for iron foundries, electric furnaces, carbon-black and sulfuric acid plants;

(h) exchange of research work and results of the studies, along with bilateral consultations. The work accomplished at the first stage permits to define the profile of scientific, engineering, and economic cooperation between the two countries.

The rise in the exchange of goods between the countries in the period 1976–1980 will amount to (percentages)

Years	1976	1977	1978	1979	1980
Deliveries:					
from Poland to Czechoslovakia	100	134	204	244	332
from Czechoslovakia to Poland	100	100	100	110	110

Among the major work to be accomplished as planned for the near period are:

In the Fan Expert Group

— completion of the preparation of the specialist agreements in the field of fans (specialisation of Poland and Czechoslovakia);

— preparation of the draft cooperation agreement on fans (cooperation on the part of Poland);

— coming to an agreement as to assortment of fans designed for cooperation and specialisation;

— signing the specialisation agreements.

In the Ventilation and Air-Conditioning Expert Group

— completion of the preparation of the specialist agreements in the field of air conditioning (specialisation of Czechoslovakia);

— selection of some other products suggested for specialisation on the part of Poland and Czechoslovakia;

— the technical information exchange on the heating and ventilation equipment form the viewpoint of their standardisation;

— preparation of a symposium in Prague on the Polish Production Program in the Air-Conditioning Industry;

In the Emission Control Expert Group

— completion of the preparation and signing the specialist agreement in the field of emission control (Polish specialisation);

— selection of some other products suggested for specialisation on the part of Poland and the exchange of technical information;

— coming to the agreement on cooperation of production in the field of emission control equipment.

In the Scientific and Engineering Cooperation Expert Group

Continued exchange of information, and results of research project and continuation or initiation of consulting in the fields of

— optimisation of the fabric filter design;

— manufacture of filter materials;

— elaboration of the filter materials catalogs;

— air-conditioning equipment control;

— distribution of air in the air-conditioned devices;

— heat recovery;
— measurements of the fan noise and vibrations, etc.

It should be pointed out that the Polish-Czechoslovak cooperation in the field of ventilation, air-conditioning and emission control equipment has been and will be of advantage for both the parties involved. This cooperation enables a mutual and more thorough getting-to-know of the parties, establishing in which products the parties attain far better and more efficient performance characteristics of the devices and installations, which may undoubtedly become a sound premise for the future socialist division of labor.

For a further development of the economic, scientific and engineering cooperation with the Czechoslovak partner, the following requirements should be met, namely:

— further selection of the assortments of products in the line of pertinent equipment and installations for cooperation and production specialization;
— introduction by both parties a severe control of the accomplishments of mutual deliveries in years 1976 till 1980;
— broadening the subject matter of the scientific and engineering cooperation within the scope of production and management organization, information, standardization and unification;
— continued more extensive organizing of symposiums in both countries on the manufactured equipment and installations;
— implementation of new methods of the bilateral Polish-Czechoslovak cooperation.

Prepared by W. Ciszewski

Scientific Information Cooperation between the Polish People's Republic and the USSR

In 1976 a uniform scientific information subsystem for chemistry and chemical technology will be launched. This will be put into existence in conformity with the resolution of the Management of the Polish Academy of Sciences and the National Center for Scientific, Technical and Economic Information, and on the basis of the bilateral agreement made on the cooperation in the domain of scientific information between the All-Union Scientific and Technical Information Institute of the USSR Academy of Science and the Polish Academy of Sciences Scientific Information Center.

The subsystem in question will be operative within the framework of the integrated automated scientific information system ASSISTENT.

The information activity will be based upon the information service covering the whole world's literature. Under this service the domestic users will be receiving signal information bulletin, edited in 39 series to cover all the fields of chemistry and related areas. The signal chemical information will be provided by the Chemical Information Office of the Scientific Information Division in Poznań, which will be issuing a journal, *Polish Scientific Periodicals Contents. Chemistry*, containing the contents of the Polish chemical periodicals. The aim of the publication will be to provide alert-type information on the most recent theoretical and practical achievements in chemistry to scientists and specialists.

The *Polish Scientific Periodicals Contents. Chemistry* is planned for domestic and foreign users. In this connection the table of contents of periodicals is to be provided in three languages, namely, in Polish, English, and Russian.

On the basis of the information received from individual editor's offices of the journals, the Chemical Information Office will be preparing abstracts of the selected papers and will make up bibliographic listings for the publications: *Referativnyi Zhurnal. Khimiya* and *Signalnaya informatsiya*.

Prepared by J. K.

Development of the Emission Control Equipment Industry

The rapidly raising demand of our national economy for high-performance emission control equipment in Poland in these days cannot pass unnoticed.

The expected emission volume in 1975 will amount to 3050 thousand tons particulates and 4300 thousand tons SO_2, which will result in damage estimated at about 40 billion złotys. The estimate specified includes merely the particulate and gaseous emissions discharged from point sources — that is, from stacks and other discharging devices. This does not accomodate, however, for emission volume due to mobile sources like railroad engines or automobiles or due to area sources like dumps, etc. For the correct appraisal of the atmospheric pollution level, the change of the generic structure of the emissions discharged is of significance. The change consists in a gradual decrease in the particulate emission volume paralleled by an

increase in the emission level of toxic gases such as compounds of sulfur, carbon, fluorine, and nitrogen. Among the items of the inflicted damage, next to some measurable ones like loss in material in the form of volatile or airborne particles of feedstocks, mention should be made of the corrosion of metals, increased wear of machinery, structures, and constructions, losses in agricultural crops as well as injuries to health of humans, animals, and vegetation. The estimates related to the emission volume of gaseous and particulate emissions and the level of damage caused by the latter demonstrate the range of the problem of the protection of the atmospheric air in Poland.

The drop in the quantity of the atmospheric emissions in 1973 amounted to over 137 thousand tons. Even though it shows the total of average values for particular voivodships, the declining trend is yet more visible especially in Katowice, Cracow, Wroclaw and Rzeszow voivodships. This is a result of continued modernization of industrial plants in those regions, combined with the equipping emission control systems on the emission sources. Some material objections should, however, be made in the appraisal of the beneficial trends mentioned. Of those objections are that emission control measures implemented are too slow a process as the corresponding figure is a mere 4.8% of the total emission value on annual basis. Moreover, apart from general declining trends, in Łódź, Poznań, or Bydgoszcz voivodships, a further rise in the atmospheric pollution level was observed.

From the appraisal of the state of air pollution in Poland an inference can be made that more efficient measures should be taken aimed at providing all the emitters with emission control devices with adequate supervision of proper operation of such devices.

As the result of accomplishment of the party and government recommendations concerning advance in technology, a key problem has been formulated for years 1971–1975 under the number of 10.1.1. bearing the title Development and Implementation of the Production of Advanced Ventilation Air-Conditioning and Emission Control Equipment, whose coordinator was appointed KLIMA-WENT Industry.

Accomplishment of the key problem was due to an expanded cooperation with research institutions, proper use of research results in designing work, continued work on typification and standardization of products, purchase of the licence solutions, and own inventive activity. Based on the advanced scientific and engineering solutions, a number of modern devices were put on stream, notably:

— cyclone and multicyclone collectors;
— wet-type collectors, including the on-line dynamic scrubber of the

design by the Academy of Mining and Metallurgy as well as foam scrubbers;

— fabric filters of the TWNK type and pulsed-air reversal bag filters;

— dust emission control systems for cement and clinker works as well as installations for the electric-arc furnace, cupolas, and sulfuric acid plants.

The development and mastering of the emission control technology in a large variety of manufacturing processes evidences an ever increasing designing and experimental potential and gained knowhow in this area.

A wide cooperation with numerous research institutes and universities resulted in an advanced stage of the development of new more adequate solutions in the emission control technology. This cooperation includes such entities as departments of the Polish Academy of Sciences, Technical Universities in Warsaw, Wroclaw and Gliwice, Academy of Mining and Metallurgy in Cracow, Institute of Binding Materials in Opole, Institute of Thermal Technics in Łódź, Silesian University, and others.

The patent applications in the number of over 40 as well as 80 technical standards elaborated supplement the achievements of own engineering thought. Based on the accomplishments made in the field of emission control technology, it can be said unquestionably that thanks to the work of Polish researchers, engineers, designers and constructors, production organizers, within less than six years a new branch of the domestic industry of the emission control equipment on an European level has been created. Naturally, this does not imply that all the problems from the province of the atmospheric pollution control have already been solved. The question of the treatment of toxic waste gases still remains to be tackled. In spite of partial solutions accomplished as concerns absorption adsorptions, and catalytic afterburning of gaseous pollutants, the results of research and designing projects indicate that the emission control techniques on a commercial scale for treatment of oxides of nitrogen, sulfur, and carbon and of fluorine compounds and mercaptans are not satisfactorily worked out. The gas treatment processes not fully developed yet in the world will be the target of research and designing work in the years to come.

In 1976 to 1980 the work mentioned will be continued under the 0.4 key problem No. 10.1.

As can be seen, the emission control equipment industry in Poland can boast of some achievements but it also meets with some obstacles in its development. A serious hindrance faced in the dynamic progress of research work is the lack of its own research base. Until now this base has been the OPAM Air Pollution Control Equipment Designing and Deliveries in Katowice, which, in view of limited space even for its own needs,

cannot develop to a scale required for the necessary research operations. Because of the lack of its own base, the pilot equipment under testing is moved all over the country to numerous workstands in industry, where they do not fulfill proper service under the manufacturing processes tested. An adequate solution will be the bringing into existence on April 1, 1978 of the Research and Development Center, which will have a new building complex equipped with necessary research and testing laboratories and designing offices. The OPAM company will then be able to focus on designing and assembling, leaving the research work with the Center.

At the moment the industry is undergoing a severe test which is the delivery of modern equipment in a quantity of 11 thousand tons for Katowice Metallurgical Plant project under construction. In the near future the industry will have to supply emission control devices for plants of old metallurgy, foundry, and cement industry as well as for the needs of power industry for which electrostatic precipitators of advanced design are delivered by the ELWO Works, Pszczyna. The prospects for development of the industry were determined on the basis of forecast analysis which resulted in the document entitled The Forecast for the Development of Production and of Demand for the Air Pollution Control Equipment in Poland for Years 1976–1990. The forecast elaborated not only describes the run of the essential elements of the production balance of and the needs for the equipment in point, but it equally outlines the growth trend in the new industry in our country, inclusive of its complex organizational, engineering and economic conditions. The balance of needs and their meeting, which is an integral part of the forecast, exhibits a pronounced growth trend of the needs of national economy in the area of air pollution control equipment.

An appreciable growth trend of needs for the air pollution control equipment reflects itself correctly in the suitable rise in the production capacity in the plants of the industry. In balancing the needs with necessary production volume the major part will be played by the production potential of the KLIMA-WENT Industry plants.

Prepared by Dr. W. Rejer

PATENT REVIEW

Air-Cushion Cyclone Separator

Inventors: A. Szczyrek, M. Sachora, K. Boroń, J. Głuszek
Patent owner: Technical University of Wrocław
Filed: January 30, 1973
Cl.: 50e, 3/10
Provisional Patent No.: 78878

The object of invention is an air-cushion cyclone separator designed for separation of mixtures of granular solids. The separator consists of cyclone shell *1* provided in its upper section with a tangential inlet *2* of the dust-laden gas. Coaxial receivers *3*, *4*, *5*, and *6* of particular fractions

are fixed in the bottom of inside shell *1*. Tangential outlets *7*, *8*, *9*, and *10* are attached to receivers *3*, *4*, *5*, and *6*. Secondary air inlet *11* is provided at the bottom section of shell *1* so that the air is fed tangentially, and the air cushion *12* is produced inside shell *1* over receivers *3*, *4*, *5*, and *6*. The air containing a mixture of granular solids is fed to the device by tan-

gential inlet *9*. At the same time, and in the same direction with the dust-laden gas, secondary air is delivered through tangential inlet *11*. In the inertial force field the tangentially fed mixture of granular materials undergoes classification according to the specific gravity and size of grains. Individual fractions enter concentric receivers owing to the difference in the air flow rate in outlets *7*, *8*, *9*, and *10*. The secondary air gives rise to an air cushion *12*, thereby ensuring easy control of the separation process.

P. P.

Method for Dust Removal from Gases

Inventors: Toshiri Tabaci, Tuyotaro Kawate, Shohei Maeno
Patent owner: Mitsui Toatsu Chemicals Inc., Tokyo
Filed: December 12, 1971
Cl.: B0e, 4/01
Patent No.: 77078

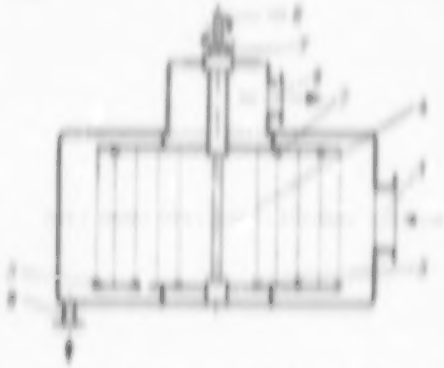
The object of invention is a method for dust precipitation from gases, and particularly the method for removal of particulates which are soluble in a solvent with the use of an improved-performance filtering material. The method, according to the invention, enables the extraction of dust from a gas stream and consists, analogously to the process in which a gas stream is allowed to pass through a porous bed impregnated with a dust solvent, in allowing a gas stream to pass through a bed of foam material of open-cell structure of a porosity over 80%. Prior to making the gas stream pass through the bed, the gas stream is preferably washed with the solvent, so that most of the dust could be washed into the solvent. The method of dust precipitation from gases consists in passing these gases through the porous bed, and the gas stream is allowed to pass through a foam material bed of an open-cell structure of a porosity over 80%. The porous material used can be polyurethane foam, rubber foam, glass wool or felt. The gas is sprayed with the dust solvent prior to its being allowed to pass through the porous bed, which results in the fact that most of the dust is washed out by the solvent. The porous bed is arranged in the way to make the angle between the bed face and the horizontal smaller than 120°, and the solvent flows freely down over the filter bed surface at the gas outlet side.

P. P.

Multistage Rotary Filter for Continuous Cleaning the Gas from Drops of Liquid and Mist

Inventors: *J. Ugarcovic, J. Rajcevinski*
Patent owner: Institute of Inorganic Chemistry, Obrenovac
Filed: February 11, 1972
Cl.: 13e, 3/01
Provisional Patent No.: 74808

The object of invention is a multistage rotary filter for continuous cleaning the gas from drops of liquid and mist. The device, according to the invention, by means of continuous, opposite rotary motion of cylindrical partitions, employs the effect of pressure differences which arise from the passing the gases through rotating filtering partitions and from the action of centrifugal and Coriolis forces that set up between the partitions. Furthermore, the rotating filtering partitions that rotate in opposite direction give rise to a kind of continuously varying dense matt of a variable gas path through the partition openings. This contributes to an increased



number of collisions between the particles of airborne liquid, with their resultant coalescence and separation. The multistage rotary filter for continuous cleaning the gas from drops of liquid and mist consists of casing with an inlet *1* and an outlet *9* of cleaned gas and an outlet stub pipe *8* for the separated liquid. A drum composed of an upper plate *2* and a bottom plate *3* is fitted on two shafts rotating in the opposite direction *6, 7* to said plates coaxial partitions permanently secured by one side. Said partitions are provided with self-sealing rings on the opposite side of their permanent securing. The mist-containing gas is supplied through inlet tube *1* with subsequent removal of the liquid on passing through the openings of the filtering partitions which rotate in the opposite direction. Conti-

nuous variations in the direction of the gas path and pulsations in the pressure of gas passing through the successive partitions give rise to frequent collisions of liquid particles, which results in their coalescence under the effect of centrifugal forces and collection of the liquid near the bottom section of the filter casing, from where it is discharged through stub pipe 6, and the cleaned gas flows toward outlet stub pipe 8.

P. P.

Method for Prevention of Deposit Precipitation from Crude Gas

Inventors: M. Stoś, P. Malczyk, W. Sosnowski, N. Amas-Amirbekowa, B. Sosnowska
Patent owner: S. Staszyński Nitrogen Plant in Tarnów
Filed: December 19, 1973
Cl.: 12e
No. of application: P-167690

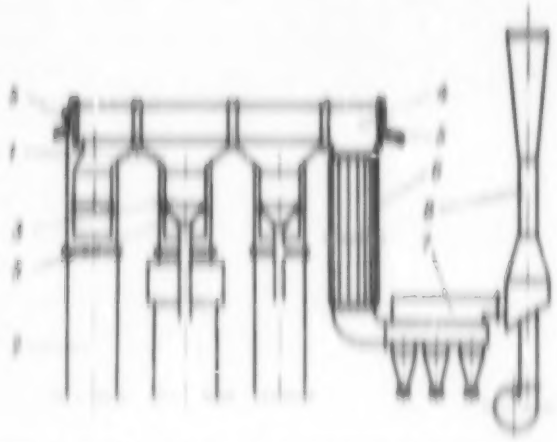
To prevent deposits from precipitating from the crude gas produced from coal or crude oil processing or from natural gas, upon cooling of the gas in a scrubber, at the time the gas is being delivered through a pipeline from the selective purification scrubber, according to the invention, steam and water or hot water is injected into the gas stream in a quantity and of a temperature that erects the gas temperature to drop below the temperature the gas attained upon the initial cooling.

P. P.

Device for Dust Control of Flue Gases Particularly from Cupolas

Inventors: M. Kamiński, H. Wendt, A. Kot
Patent owners: PIOMIEŃ Foundry Designing and Equipment Enterprise, Cracow
Filed: September 28, 1973
Cl.: 12e, 3/01
Provisional Patent No.: 78199

The object of invention is a device for dust control of flue gases in particular from cupolas in a system of two alternately operated cupolas with a common hot-air stove. The device is equipped with a head closing the cupolas stacks and the hot-air stack, and has a preliminary dust collection chamber *1* connected by means of rotary gates *2* to stack head *3*, which are combined with a common header *4* provided at its ends with



explosion doors *5*, said header being connected through air cooler *6* to a cyclone battery *7* with an ejector *8* attached to the battery end. The dust control process with the device, according to invention, eliminates the use of disposable collecting agents, and, owing to the preliminary stage of dust collection provided, it ensures lesser wear of the capture system pipes and of the dust control device itself. Due to the air cooler where the flue gases are cooled, the device can be of smaller size and high collection efficiency can be achieved.

P. P.

CONTENTS

Szymonik, S., Moskwa, A. S., Wojtkowska-Atol, E., nitrogen Dioxide Removal from Dilute Gases by Absorption in a Magnesium Hydroxide Suspension 1

Parczewski, W., A Novel Damage Prognostication Approach for the Areas Adjacent to Industrial Plants 10

Rzeprzycki, A., An Optimum Air Pollution Data Collection and Analysis System 14

Chobotska-Cabaj, E., Urbarska, E., Estimation of Individual Dust Hazard in the Working Environment in a Superphosphate Plant 21

Frost, E., Assessment of the Performance of the Stoker-Fired Boiler Exhaust Control Equipment 28

Seipler, A., The Influence of Urban and Industrial Areas upon the Local Climate 40

Polemics 51

Industrial Briefs 57

Patent Review 65